

DOCUMENT RESUME

ED 349 941

IR 015 672

AUTHOR Martin, C. Dianne, Ed.; Murchie-Beyma, Eric, Ed.
 TITLE In Search of Gender Free Paradigms for Computer Science Education. [Proceedings of a Preconference Research Workshop at the National Educational Computing Conference (Nashville, Tennessee, June 24, 1990).]
 INSTITUTION International Society for Technology in Education, Eugene, OR.
 SPONS AGENCY Association of Computing Machinery, Baltimore, MD.; IBM Corp., Atlanta, GA. Educational Systems.; National Educational Computing Conference.
 REPORT NO ISBN-1-56484-009-3
 PUB DATE 92
 NOTE 160p.
 AVAILABLE FROM International Society for Technology in Education, 1787 Agate Street, Eugene, OR 97403-1923.
 PUB TYPE Collected Works - Conference Proceedings (021)
 EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
 DESCRIPTORS Academic Achievement; Attitudes; *Computer Science; Epistemology; *Equal Education; Females; Higher Education; Information Sources; Microcomputers; Racial Bias; *Sex Bias; *Sex Differences; Sexism in Language; Teaching Methods
 IDENTIFIERS *Computer Attitudes; National Educational Computing Conference

ABSTRACT

This monograph includes nine papers delivered at a National Educational Computing Conference (NECC) preconference workshop, and a previously unpublished paper on gender and attitudes. The papers, which are presented in four categories, are: (1) "Report on the Workshop: In Search of Gender Free Paradigms for Computer Science Education" (C. Dianne Martin); (2) "Understanding Gender Biases in Computer-Related Behavior: Are We Using the Wrong Metaphor?" (Robin Kay); (3) "Gender Differences in Human Computer Interaction" (Charles W. Huff, John H. Fleming, and Joel Cooper); (4) "Gender and Attitude Toward Computers" (James R. Aman); (5) "Female Students' Underachievement in Computer Science and Mathematics: Reasons and Recommendations" (Lesley S. Klein); (6) "Implications of the Computer Culture for Women of Color" (Carol Edwards); (7) "Strategies for Involving Girls in Computer Science" (Valerie Clark); (8) "A New Introduction to Computer Science" (Danielle R. Bernstein); (9) "Restructuring Departments for Equality" (Henry Etzkowitz, Carol Kemelgor, Michael Neuschatz, and Brian Uzzi); and (10) "Gender Equity--A Partial List of Resources" (Cindy Meyer Hanchey). An additional paper and report are appended: "Epistemological Pluralism: Styles and Voices within the Computer Culture" (Sherry Turkle and Seymour Papert); and "Becoming a Computer Scientist: A Report by the ACM Committee on the Status of Women in Computing Science" (Amy Pearl, Martha Pollack, Eve Riskin, Becky Thomas, Elizabeth Wolf, and Alice Wolf). The gender equity resources listed include books, articles, and brochures; training modules; technical assistance modules; publications from the National Science Foundation; and organizations. (ALF)

ED349941

12015272

NECC
monograph



PUBLICATION

IN SEARCH OF GENDER FREE PARADIGMS FOR COMPUTER SCIENCE EDUCATION

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

- ☐ This document has been reproduced as received from the person or organization originating it.
- ☐ Minor changes have been made to improve reproduction quality.

- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL
IN OTHER THAN PAPER COPY HAS BEEN
GRANTED BY

D. Moursund

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)."

EDITED BY C. DIANNE MARTIN AND ERIC MURCHIE-BEYMA

2

BEST COPY AVAILABLE

About the Project

Through the efforts of the NECC '90 Conference Chair, Dr. John McGregor, and with financial support provided by IBM and the ACM Precollege Education Subcommittee, two research workshops were added to the NECC '90 agenda. This monograph is a result of one of the research workshops. NECC Research Workshops provide a unique forum for researchers to share ideas in special areas of educational computing. This collection of articles by researchers in gender-issues in computer science provides recommendations to solve the problem of the declining number of young women selecting computer science majors.

Editors

C. Dianne Martin, *Assistant Professor, Department of Electrical Engineering and Computer Science,
The George Washington University*

Eric Murchie-Beyma, *International Society for Technology Graduate Fellow, ISTE Washington Office*

NECC Monograph Editorial Review Board

Diana Harris, *University of Iowa*

John McGregor, *Clemson University*

Dave Moursund, *University of Oregon*

James L. Poirot, *University of North Texas*

Book Design and Production

Tamara Kidd, *International Society for Technology in Education*

Production Assistance

Ian Byington, Lori Novack, and Kim Ralston, *International Society for Technology in Education*

This book has been produced using *Aldus PageMaker*

© International Society for Technology in Education, 1992

1787 Agate Street, Eugene, Oregon 97403-1923

Order Desk: 800/336-5191

Phone: 503/346-4414 Fax: 503/346-5890

CompuServe: 70014.2117 Internet: ISTE@Oregon.uoregon.edu

ISBN 1-56484-009-3

IN SEARCH OF GENDER FREE PARADIGMS FOR COMPUTER SCIENCE EDUCATION

EDITED BY C. DIANNE MARTIN AND ERIC MURCHIE-BEYMA

©International Society for Technology in Education, 1992
ISBN 1-56484-009-3

Acknowledgments

I would like to express appreciation to the NECC '90 Program Chair, Professor John McGregor of Clemson University, for including the workshop in the 1990 NECC program and the Education Division of IBM and the Precollege Education Subcommittee of the ACM for providing funding for the workshop. Of course, many thanks are due to Anita Best and the staff at the ISTE International Office for their assistance in production of the monograph and to Jeff Campbell of George Washington University for typing assistance.

—CDM

Contents

Introduction	vii
--------------------	-----

I. The Power of Paradigms

Report on the Workshop: In Search of Gender Free Paradigms for Computer Science Education. <i>C. Dianne Martin, The George Washington University</i>	1
Understanding Gender Biases in Computer-Related Behaviour: Are We Using The Wrong Metaphor? <i>Robin Kay, University of Toronto, Canada</i>	9

II. The Research Findings

Gender Differences in Human Computer Interaction <i>Charles W. Huff, St. Olaf College; John H. Fleming, University of Minnesota; Joel Cooper, Princeton University</i>	19
Gender and Attitude Toward Computers <i>James R. Aman, Wilmington College</i>	33
Female Students' Underachievement in Computer Science and Mathematics: Reasons and Recommendations <i>Lesley S. Klein, Pace University</i>	47
Implications of the Computer Culture for Women of Color <i>Carol Edwards, Southern Coalition for Educational Equity</i>	57

III. Strategies for Change

Strategies for Involving Girls in Computer Science <i>Valerie Clcrk, Deakin University, Australia</i>	71
A New Introduction to Computer Science <i>Danielle R. Bernstein, Kean College of New Jersey</i>	87
Restructuring Departments for Equality <i>Henry Etzkowitz, SUNY Purchase and Columbia University; Carol Kemelgor, New York University; Michael Neuschatz, American Institute of Physics; Brian Uzzi, SUNY Stony Brook</i>	93

IV. Gender Equity Resources

Gender Equity—A Partial List of Resources <i>Cindy Meyer Hanchey, Oklahoma Baptist University</i>	105
--	-----

V. Appendix

Epistemological Pluralism: Styles and Voices Within the Computer Culture
(Reprinted with permission from *Signs Magazine*,
University of Chicago Press)

Sherry Turkle and Seymour Papert, *Massachusetts Institute of Technology* 113

Becoming a Computer Scientist: A Report by the ACM Committee
on the Status of Women in Computing Science

(Reprinted with permission from the *Communications of the ACM*,
November, 1990)

Amy Pearl, *Sun Microsystems*; Martha Pollack, *SRI International*;

Eve Riskin, *University of Washington*; Becky Thomas, *Stanford University*;

Elizabeth Wolf, *Stanford University*; Alice Wu, *Stanford University* 141

Introduction

An all day preconference research workshop entitled "In Search of Gender-Free Paradigms for Computer Science Education" was held on June 24, 1990, at the National Educational Computing Conference (NECC '90) in Nashville, Tennessee. Organized and chaired by C. Dianne Martin of The George Washington University, the workshop was jointly sponsored by NECC, the Education Division of IBM, and the ACM Subcommittee on Precollege Education. The premise was that the decline in the number of young women selecting computer science majors was attributable to a male-oriented paradigm in computer science. The workshop brought together researchers who had been conducting gender-related research in computer science education to examine all of the issues and to make recommendations to solve the problem.

The workshop format included nine research presentations followed by the division of the group into three working subgroups, each charged with the responsibility to develop a set of recommendations to address the problem. The presenters were Danielle R. Bernstein from Kean College of New Jersey; Valerie Clarke from Deakin University, Australia; Carol Edwards of the Southern Coalition for Educational Equity; Henry Etzkowitz from SUNY and Columbia University, New York; Cindy Meyer Hanchey from Oklahoma Baptist University; Charles Huff from St. Olaf College, Minnesota; Robin Kay from the University of Toronto, Canada; Lesley Klein, Pace University, New York; and Elizabeth Wolf representing the Women of the ACM (WACM) Subcommittee.

This monograph includes the papers delivered at the workshop as well as a previously unpublished paper on gender and attitudes based on a Ph.D. dissertation by James Aman. The monograph is divided into six sections. The "Power of Paradigms" provides an overview of the topic and a summary of the papers and a framework for examining the issue. "The Research Findings" contains four papers that present data on gender and achievement in math, science, and computer science. "Strategies for Change" contains three papers that suggest strategies for addressing the gender gap in computer science. "Gender Equity Resources" contains a comprehensive bibliography of resources related to gender equity compiled over the past five years. The resources include research articles, books, videos, computer software, inservice training programs for school districts, national reports, and organizations involved in the development of non-gender specific products. The appendix contains a position paper contributed by Sherry Turkle and Seymour Papert of MIT, that has subsequently appeared in *Signs Magazine*, and the final report of the ACM Committee on the Status of Women in Computer Science, that has subsequently appeared in the *Communications of the ACM*.

I. THE POWER OF PARADIGMS

Report on the Workshop: In Search of Gender Free Paradigms for Computer Science Education

C. Dianne Martin

Department of Electrical Engineering and Computer Science
The George Washington University
Washington, D.C.

Problem

There has been a significant decline in students enrolling in computer science programs over the past three years. This decline warrants the serious concern of both computer professionals and educators since it will eventually have an adverse impact on the profession, on the economic health of the nation, and on national security. The most significant portion of the decline can be attributed to young women. This is particularly startling because computer science is a relatively new field that has been open to women since its beginning approximately twenty-five years ago. When the flood of computer science undergraduate students hit the universities from 1978-1985, almost half were women.

The Power of Paradigms

In research the particular research paradigm determines not only how to study a problem, but also what problems can be studied based upon the constraints of the methodology. The same can be said about the intersection of computer science and gender. One premise is that the decline in young women selecting educational curricula that lead to careers in computer science can be attributed to the existing educational paradigm that separates studies of science, math, and computer science from studies of the humanities starting in the secondary schools. Several studies have suggested that the way computer science material in particular is taught at the elementary and secondary levels is gender-biased toward males. If a new gender-free paradigm can be created that presents an integrated approach to these disciplines, more young women would continue to be interested in them as future career options. This paradigm should include greater attention to values, human issues, and social impact as well as to the mathematical and theoretical foundations of computer science. It would also be of great value to examine this question as it relates to ethnicity as well as to gender.

Eric Roberts (1989) found the unique aspect of computer science as a discipline to be the encouragement of highly focused, almost obsessive behavior as a road to success. Males have been given license by society to be obsessive, whereas women are expected to be more "balanced." This view echoes Sherry Turkle's comments in her book *The Second Self* (1984), where she examines the social and psychological

aspects of the computer revolution and presents descriptions of computer hackers at MIT as the ultimate "nerds," antisocial and obsessive to the extreme in their behavior. Such a paradigm for computing is decidedly unappealing to women who are nurtured to value interpersonal relations.

In their well-known study "Poolhalls, Chips and Wargames (1985)," Kiesler, Sproull, and Eccles of Carnegie Mellon University examined why computers seemed to be more attractive to boys than girls. They offered a cultural framework for explaining the apparent gender differences and suggested that the world of computing was more consistent with male adolescent culture than with feminine values and goals. Computing itself was neither inherently difficult nor uninteresting to girls, but computer games, educational software, and curriculum were designed using a male paradigm.

In looking at the undergraduate and graduate computer science curriculum, again the paradigm issue enters in. The typical student that most professors have in mind when they design their courses, problems, and lectures is the white male. A 1987 Burton study found that most female undergraduate and graduate students in computer science experience a lack of role models, feelings of isolation, and a reduced social support structure when compared to their male counterparts. So-called "killer" courses taught in the freshman year—courses designed to cull rather than cultivate students for the discipline—have affected both female and minority students more adversely than white male students. Women are attracted to and learn better in a cooperative rather than a competitive environment. The typical computer science curriculum taught by predominantly male professors, many of whom are foreign and come from cultures that do not regard females as serious students, all contribute to what Sheila Widnall (1988) describes as the "chilly classroom" for female students.

A Cooper Union study (1989) surveyed female science, engineering, and computer students and professionals and found that the chilly classroom carries forward into a chilly work environment as well. Researchers found that 70% of the women felt they had to work harder than their male counterparts, 50% felt that they viewed ethical issues differently than their male counterparts, 39% felt that they would be penalized if they took maternity leave, 30% felt that the wives of their male colleagues felt threatened by them, 58% felt that harassment of some sort was prevalent in the workplace, and 78% felt they received comparable pay when they started, but were not promoted as rapidly. Another study supported the last belief. It found that most women begin with comparable wages, but within 10 years, they earn 25% less than males.

In his paper "Understanding Gender Biases in Computer-Related Behaviour: Are We Using the Wrong Metaphor?" Kay suggests shifting from a construct metaphor that masks process, emphasizes generalization, and produces arbitrary interpretation of results to a process metaphor that would encompass dynamic and complex interactions, social construction, and context. The goal would be to provide a coherent model to explain the complex interaction of many factors. It would allow researchers to move from merely identifying gender differences to understanding them.

A gender-free paradigm for computing probably does not exist. What is needed instead is the pluralistic approach called for in the position paper submitted to the workshop and found in the appendix by Turkle and Papert, "Epistemological Pluralism: Styles and Voices Within the Computer Culture." They stated that both the popular and technical culture have presented computation as the ultimate embodiment of the abstract and formal, ignoring the concrete and personal aspects of computation. In their in-depth examination of successful programmers at many different levels over two decades, they found a "diversity of approaches to programming that suggests that equal access to even the most basic elements of computation requires accepting the validity of multiple ways of knowing and thinking." Despite the dominant ideology of the computer culture that privileges the structured, hierarchical, "black box" style, they cite evidence that the main difference between the formal and concrete approaches to programming is not in the quality of the final product, but in the process of creating the product. New research in the areas of ethnography of science, psychology, and feminist scholarship point to the power of concrete, contextual reasoning in a wide range of domains.

The Research Findings

Huff, Fleming, and Cooper describe a research program that has investigated the social psychology of human computer interaction in their paper, "The Social Basis of Gender Differences in Human Computer Interaction." In a number of carefully constructed experiments, they have confirmed that males and females approach the task of computing in recognizably different ways and that the design of the software itself carries with it a gender-loaded paradigm that can produce differential stress to users depending upon gender.

In the study "Gender and Attitude toward Computers," Aman looked at two broadly gender-appropriate computer applications, problem solving and written composition, as well as overall attitude indicators. The study was conducted at two gender-segregated high schools, one male and one female. It found that gender was a significant predictor of computer attitude and that females held persistently more positive computer attitudes than males. On the other hand, females showed less confidence in their abilities on the computer. Additionally, males overwhelmingly spent substantial amounts of time each week on the computer when compared to females.

In her paper "Female Students' Underachievement in Computer Science and Mathematics: Reasons and Recommendations," Klein synthesizes past studies to trace the behavior of female students in mathematics and attitudes toward computer science from elementary mathematics through college mathematics. Results of previous studies concluded that girls excel in such areas as computation skills and symbolic relationships while boys dominate in spatial relations and problem solving. While women generally did not agree that mathematics was a "male domain," they reported more math anxiety. Males, on the other hand, had more confidence in their

ability to learn math and stated a significantly greater intention to take math courses in the future than women. Men perceived women to be not as able to handle computers. Several studies suggested that masculine software design has precluded girls from developing a sense of "ownership" toward computers, beginning with video arcade games where girls are usually the spectators. The Klein study concludes with recommendations to clarify and formalize computer science curriculum at the precollege level and make mandatory an introduction to computer science for all high school students, incorporate computer usage across the curriculum to provide a variety of computer experience for all students, decrease competitiveness in the design of education software, and incorporate cooperative group projects in the classroom as often as individual projects.

In the paper "Implications of the Computer Culture for Women of Color," Edwards reports that young women of color experience all of the gender problems found in previous studies to a greater degree. They face tremendous cultural and educational barriers that prevent most of them from venturing into majors and therefore careers in math, science, engineering, and computer science. They experience the educational barriers of a frequent lack of resources in predominantly minority schools, lower teacher expectations, more substitute teachers, less experienced teachers, and the frequent relegation to lower educational tracks, even through tracking has been found to benefit only the top 1% of students. The cultural barriers include the lack of role models, the lack of encouragement by parents and teachers, the responsibility for the care of siblings, and an anti-intellectual culture that measures self-esteem in non-academic ways. Sadly, the effects of disadvantage are cumulative; that is, the combination of being poor and minority and female lowers perceptions and aptitudes towards math and computers proportionally to the level of disadvantage.

Strategies for Change

Clarke describes research conducted over the past five years that examined gender-based factors related to primary, secondary and university students in her paper "Strategies for Involving Girls in Computer Science." She identifies 13 barriers inhibiting girls participating in computing and suggests practical strategies for overcoming them. At all levels she found gender stereotyping and expectations to be a major cause of the differences. She also found gender stereotyping to be situational, as illustrated by one study in which a coeducational primary school was compared to an all-girl primary school. In her research Clarke has noted the presence of sex bias in parental and teacher behavior reflected by greater home ownership of computers by families with boys and encouragement to enroll in summer camps and courses for boys.

At the secondary and university levels, the major factors reflecting gender differences were previous computer experience, type of computer experience (i.e., word processing versus programming), differences in mathematics experience related to high school math courses taken, male-oriented software design, the different social

needs of girls and boys, and the perception of computing as a male activity. The dearth of female role models and lack of encouragement by high school counselors steering girls toward computer science were also seen as factors affecting female enrollment in college computer science.

In her paper "A New Introductory Course for Computer Science," Bernstein states that her research has shown that the feeling of self-efficacy is a major predictor of success in computer science. Self-efficacy with computers can be defined as the feeling that one is in control of the machine and can make a difference in the machine's operation. As a group women rate themselves lower than men for perceived self-efficacy on computers. The factor most influencing feelings of self-efficacy is previous experience with computers. Research has shown that from the first encounter men approach the computer as a passion or a preoccupation, whereas women view the computer as a tool to complete a specific task.

Bernstein suggests that a new curriculum paradigm for computer science courses, especially the introductory course, is needed to increase confidence and the sense of being in control. This new approach would be based upon the use of applications packages such as spreadsheets and databases to introduce the fundamental concepts of computer science, rather than programming. Such a course would tend to be an equalizer, empowering those who had not had high school programming as well as those who had. Women would see the usefulness of computers immediately and might thereby have incentive to continue studying about computers.

Female faculty and graduate students in four academic departments (chemistry, physics, computer science, and electrical engineering) at two research universities are surveyed by Etzkowitz et al. in their paper "Restructuring Departments for Equality." They find that all the traditional norms of the academic system work to exclude women or hold them back on the promotion ladder. Women who attempt to define an alternative scientific role, balancing research with other roles and limiting time at the work site, encounter structural obstacles such as severe limitations on arranging part-time appointments during pregnancy or child-rearing years. Men in some areas of research such as theory are resistant to participation by women. Female graduate students with children often have difficulties finding thesis advisors who understand their family responsibilities.

Etzkowitz et al. concluded that the development of a critical mass of women faculty and graduate students within a department would result in a reduction of structural barriers, positively affect the culture of a department, and either restrict the expression of or change negative male attitudes, thereby increasing the success rate of women faculty and graduate students in achieving tenure, promotions, and degrees. To accomplish this, they proposed the involvement of students and faculty in the faculty recruiting process, a change in the tenure structure to allow a more flexible time clock, and the removal of the geographic constraints encountered by female graduate students who may not be in a position to move to another location after graduation but are prevented from being hired by their department.

The report of the ACM Subcommittee on the Status of Women in Computer Science (Pearl, et al.) entitled "Becoming a Computer Scientist" is included as a reprint in the appendix. The preliminary committee findings were first presented at the workshop. The article was subsequently published in the Communications of the ACM, but it was the intention of the committee to have the article appear in this monograph as a part of the body of research on gender issues. It presents the discouraging statistics from the computer science pipeline over the past decade that reveal the declining participation of women at all levels in the field. Approximately 36% of all B.S. degrees, 30% of all M.S. degrees, 11% of all Ph.D.s, and only 6.5% of all computer science faculty appointments are earned by women. The numbers are more encouraging in industry where 30% of all employed computer scientists are women. However, even in industry where women find a more flexible environment better suited to their special needs, they still encounter the glass ceiling and the "mommy track" mentality blocking career advancement. This preliminary report calls for a systematic study of the structural changes needed in both academia and industry to reopen the pipeline for women.

Recommendations from the Gender Workshop

After the paper presentations, the workshop participants formed three subgroups to discuss the issues of *exposure*, *attraction*, and *retention* of young women to computer science. Each group was asked to identify major problems and obstacles that hindered women in each area and to recommend both visionary and practical solutions to the problems.

Exposure: Regarding early exposure to computers and computing, the first subgroup identified gender stereotyping, low expectations, limited access to computers, bias in counseling by teachers and parents, male-oriented software, and the lack of role models in the media and in daily life as the major obstacles to providing early, positive exposure to computers for girls. The group recommended that to counteract these obstacles there should be an immediate national effort at the middle school level to develop programs to appeal to girls, since that is the age when most girls lose interest in math, science, and computers. They saw the need to improve curriculum, educational software, and teacher training to address this concern. The focus on computers at this level should not be on programming, but on the relevance of the computer to social needs through the use of applications software in cooperative learning environments. Computers should be used throughout the curriculum with equitable access for all children.

Attraction: Similar themes were discussed by the second group who looked at why girls are not attracted to computers and computer science. They identified computer games and software, lower home ownership of computers, parent/teacher expectations and advising, and the early emphasis on programming as the major culprits in turning off girls to computers. They suggested a national parent education program through the media and parent teacher organizations, inservice training for

teachers and guidance counselors, the allocation of more resources to provide more computers in schools, and a more tools-oriented approach to computer studies in both high school and college. They also suggested an active role by industry to provide role models in the schools, to develop gender-neutral software, and to provide funding for special projects related to attracting young women to computer science.

Retention: The third group looked at the retention issue since the data have shown that simply attracting women to computer science is not enough. There is a significantly higher dropout rate among female computer science students than among their male counterparts. Recommendations from the third group were targeted for high school, college, and graduate computer science programs. They recommended structured labs using group projects based upon cooperative learning models; formal peer, faculty, and alumni mentoring programs for women and minority students; pairing of college students with high school students, and pairing of graduate students with college students to provide positive peer role models; guest lecture programs fed by government and industry to provide role models; a computer for every student in their dorm room; more financial aid in the form of grants rather than loans; and programming courses that emphasize computer applications and focus on reading good programs before writing them. The final recommendation of this group was related to the reward structure for faculty members. Recognizing that the programs they recommended take a tremendous amount of time to develop and administer, they proposed that the criteria for tenure and promotion should include developing new teaching strategies, developing innovative curriculum, mentoring, and administering programs to meet the needs of special categories of students as well as the traditional research and publishing.

References

- Burton, M.D. (1987). Gender differences in professional socialization: A study of women and men becoming computer scientists. Technical Report, Pittsburgh: Carnegie Mellon University.
- Cooper Union 1989 national survey of undergraduate women engineering students. (1989). The Cooper Union for the Advancement of Science and Art, New York, NY.
- Cooper Union 1989 national survey of women engineers. (1989). The Cooper Union for the Advancement of Science and Art, New York, NY.
- Turkle, S. (1984). *The second self: Computers and the human spirit*. New York: Simon and Schuster.
- Kiesler, S., Sproull, L., & Eccles, J.S. (1985). Poolhalls, chips and wargames: Women in the culture of computing. *Psychology of Women Quarterly*, 9, 451-462.
- Roberts, E. (1989) Women and computer science. *Tough Questions*, Student Pugwash Magazine, Fall issue, 4-5.
- Widnall, S.E. (1988). Voices from the pipeline. *Science*, 214, 1740-1745.

About the Author

C. Dianne Martin (B.A., Economics and Mathematics Education, Western Maryland College; M.S., Computer Science, University of Maryland; Ed.D., Teacher Education, The George Washington University) is an Assistant Professor in the Department of Electrical Engineering and Computer Science at The George Washington University. She is the Associate Executive Director for the ISTE Washington Office. Her current research interests include the use of hypermedia in qualitative research, school district implementation of microcomputers, and the presentation of ethical and social impact issues in computer science.

Understanding Gender Biases in Computer-Related Behavior: Are We Using the Wrong Metaphor?

Robin Kay
University of Toronto

Abstract

A number of researchers of have used a construct metaphor to investigate and explain gender differences in behaviors toward computers. A typical study uses paper-and-pencil data gathering techniques to develop and assess a variety of independent constructs based on attitude, ability, and use. Males and females are then compared on the basis of these constructs. Although this metaphor provides concise, easily understood descriptions of the data, it suffers from several drawbacks, the most serious being the neglect of process. Other problems include arbitrary analysis of results and a bias toward general as opposed to specific needs of the individual. An argument is made here to use a process metaphor, employing verbal protocol analysis, to investigate computer-related behavior. A "contextual module," synthesizing factors such as declarative and procedural knowledge, goals, affect, reaction to typical problem situations, self-concept, and code of conduct, is offered as a guide for protocol analysis. It is speculated that the process metaphor will help provide: 1) an understanding of the dynamics of human-computer interaction; and 2) a rich source of information for developing instructional strategies for using computers.

Many researchers, including myself, have used a construct metaphor to examine gender biases in computer-related behavior. Investigations consist primarily of comparing females and males on a number of independent constructs such as computer attitudes, computer literacy, and locus of control (see Kay, 1986; 1989a, 1989b, 1990a, 1990b). The standard protocol for this kind of research is to administer questionnaires designed to assess particular computer-related constructs. Internal reliability (but rarely validity) estimates are offered to bolster the credibility of measures, and the final product is a three-column summary of construct scores: one column representing males, another representing females, and a third listing the statistical significance of differences between scores.

The Construct Metaphor

I have presented these kind of results to audiences and inevitably the first question asked is, "Why do you think there are differences between males and females in their behavior toward computers?" I have many ideas, hunches, and speculations, but I am at a loss to provide a rigorous, coherent model. In essence, the construct metaphor, although easily understood, offers inert, static results providing little insight as to why males and females differ in their behavior toward computers.

There are at least three fundamental reasons why a construct-based approach is theoretically and practically impotent with respect to understanding computer use: 1) the masking of process; 2) arbitrary data interpretation of results; and 3) an emphasis on general rather than specific needs.

Construct-based research methodology obscures process. The bulk of computer-behavior research has focused on "what" questions (declarative knowledge) to the exclusion of "how" and "why" questions (process) (Kay, submitted for publication). From both a theoretical and practical perspective, the truly meaningful and useful analysis illuminates our understanding of process. A list of inert relationships or propositions provide little guidance if we wish to understand and eventually modify behaviors related to computer use. For example, Kay (1989a) reported that female student teachers had a lower degree of computer-related skills, a more external locus of control, and similar attitudes when compared to their male counterparts. This list of associations is descriptively interesting (and perhaps motivating to female students) but dynamically languid. What we really want to know is how the cognitions of females influence their behavior and dispositions toward computers.

Interpretation of paper-and-pencil data, particularly interactions, is necessarily arbitrary. No amount of statistical wizardry can answer causation questions stemming from this kind of assessment. For example, a significant difference between males and females with respect to computer ability tells us nothing about what causes this difference, how ability relates to other constructs, or the extent to which gender determines this difference. Identification of paper-and-pencil constructs using statistical magic makes it very hard for the reader to conceptualize distinct modules of human-computer interaction: attitude, ability, locus of control. Unfortunately, it is very difficult to see how these constructs work together. One is forced to speculate and select connecting reasons somewhat arbitrarily. Researchers who attempt to isolate independent variables using a questionnaire format are taking out a "clarity loan" that they are unable to repay once the data are analyzed.

A construct metaphor is necessarily biased toward the philosophy of averages and universality. Scores are derived by adding up hundreds of individual scores and calculating an average. It is difficult to tease out nuances and individual differences from this average or general tendency. Keating (1989) notes, "Evidences of cognitive diversity is pervasive; understanding its sources and trajectories...is fundamental to understanding cognition."

It is necessary to use alternative metaphors to those employed in the past to get a clearer and more complete understanding of "trajectories" regarding the use of computers by males and females.

The Process Metaphor

An alternative to the construct metaphor used to study human-computer behavior is the process metaphor. The process metaphor encompasses notions such as dynamics, mechanism, complex interactions, social construction, and context. Constructs may be identified, but only in relation to other constructs. The process metaphor emphasizes understanding the process underlying behavior toward computers. The

ultimate goal is to construct a coherent, consistent model explaining the complex interaction of a number of factors.

A change in metaphor precipitates a change in data gathering methods. One such method involves the use of think-aloud verbal reports or protocols offered by subjects while they are using computers in various contexts. For example, subjects could be asked to say whatever comes into their minds while they are learning how to use a word processor. In essence, subjects are reporting what is in their short-term memory (STM) while they are attending a particular task. For a detailed discussion on how to use verbal protocol analysis, see Ericsson and Simon (1984).

Verbal report data were considered suspect during the reign of behaviorism (Ericsson & Simon, 1980), but a resurgent interest in mechanisms of cognitive process has seen a need for careful, rigorous analysis of interview and think-aloud protocols. Ericsson and Simon maintain that "verbal reports, elicited with care, are a valuable and thoroughly reliable source of information about cognitive processes." Clearly, the use of verbal reports lends itself to examining individual (as opposed to group) processes involved in computer use.

The initial product of think-aloud verbal report is a tape or video recording of a subject doing a specific task. This recording is transcribed into many pages of written text that has to be interpreted in some meaningful way. The interpretation of think-aloud data can be just as arbitrary as the interpretation of questionnaire data, and it is often useful to propose a model for analyzing the data.

One possible model is based on a list of suggestions presented by Carl Bereiter (1985) to overcome a phenomenon known as the learning paradox. Bereiter's approach was formally organized in a more recent article supporting situated learning or what he refers to as "contextual modules" (Bereiter, in press).

A "contextual module" is a kind of psychological unit that synthesizes declarative knowledge, procedural knowledge, goal structures, problem models, affect, self-concept, and code of conduct. The last two elements are likely to develop more slowly than the first five. A "contextual" approach encourages a more global and interactive understanding of computer-related behaviors. By focusing on a number of different cognitive influences simultaneously, a "contextual model" also lends itself to exploring the diversity of behaviors related to computer use.

Potential Pitfalls

Every methodology has its strengths and weaknesses. The critical factor in determining the value of a specific methodology is how useful it is in obtaining the kind of results desired. To review, the principal strength of using verbal reports in this study is to investigate process, or how cognitions combine to affect computer use. Other strengths were elaborated in the introduction. There are several weaknesses, or perhaps caveats, that should be considered when using verbal protocols including: a) theoretical difficulty in isolating interacting elements; b) the accessibility of process to consciousness; c) analysis bias; d) generalizability; and e) interference of protocol analysis with task completion.

Difficulty in Isolating Individual Elements

From a theoretical standpoint, it might be very difficult (as Bereiter suggests) to tease out individual components of a "contextual module" when analyzing transcribed reports. In fact, part of the philosophy of a contextual module is that it is erroneous, if not futile, to isolate factors involved in the learning process. The philosophy of reductionism does not apply, and the whole is predicted to be greater than the sum of its parts. Identifying specific components of the verbal report data will yield the same problems as identifying constructs from a pencil-and-paper tests.

There is no empirical defense against the anti-reductionist argument presented above, but there is one reasonable counter argument. Verbal reports may not be the ideal method for examining process, but they are better than a written test method, because they are less restrictive (no forced choice or detailed questions), and they assess process directly (by simply asking), as opposed to indirectly (through the use of statistical gymnastics). In effect, the use of verbal reports will not solve theoretical issues of reductionism, but they are probably more effective than written tests at discovering process.

Awareness of Process

Test enthusiasts might concede that, on the surface, it appears that verbal reports are more direct than paper-and-pencil methods. This would be true if the subject were completely conscious of his or her behavior, but consciousness of process is an assumption, not a fact. Written tests, on the other hand, can be analyzed using sophisticated statistical methods to uncover hidden combinations of which an individual could never be cognizant (three- and four-way interactions).

In reply to this weakness, one has to concede that verbal reports assess those cognitions of which we are conscious. Still, overt cognitions are important and have not been identified using written tests. The supposition that written data is more amenable to unveiling hidden interactions is somewhat suspect. The analysis of regression or various multivariate statistical techniques is subject to considerable arbitrariness. It would be misleading to hide behind the mathematical complexity of these procedures. Anecdotal evidence, readily obtained in a verbal report, is often necessary to interpret the morass of statistical output produced in a multivariate analysis. Verbal reports, then, are no worse and probably better than written tests for identifying conscious cognitions about computer use.

Analysis Bias

As mentioned to previously, another weakness of using verbal reports is the subjective quality of the data collected and potential biases in the protocol analysis. Simply stated, the analysis of transcripts requires a certain degree of arbitrary selection. As stated above, this arbitrariness cannot be adequately addressed using written tests, either. To counteract this subjectivity, it would be necessary to obtain inter-rater reliability of data categorization combined with a detailed description of the steps of analysis and a list of assumptions made. Furthermore, the analysis of verbal

protocols requires a certain consistency and coherence that is not required when interpreting columns of t-tests. It is scientifically acceptable in the latter analysis to simply acknowledge the existence of differences, whereas in the former, a workable model or theory, such as "contextual modules" needs to be constructed.

Generalizability

A fourth concern might be with generalizability of the small sample sizes using verbal protocols. Since one subject could generate over a hundred pages of data in a couple of hours, sample sizes of even 10 to 15 subjects become unwieldy. This fact should also be incorporated into any conclusions drawn from the verbal protocol analysis. It is clearly appropriate to test models developed using protocol analysis using a number of experimental paradigms including experimental and practical environments.

Task Interference

Critics of verbal protocol analysis have suggested that thinking aloud while performing a specific computer task could interfere with the process of accomplishing that task, thereby biasing the overall results. They argue that somewhat artificial protocols will result. Ericsson and Simon (1980) examined this issue and found that, unless recoding of information is required, think-aloud procedures do not affect the course and structure cognitions required to complete a task.

Preliminary Results

Very little verbal protocol analysis has been done in the area of human-computer interaction. One promising effort is offered by Turkle and Papert (1990). Anecdotes from thirty college students participating in their first programming course are scrutinized to support a theory that there are at least two different styles used to program: a formal, canonical style often used by men, and an ad hoc, concrete style, known as "bricolage," used by women. The authors suggest that these styles are different and equally valid, a claim that runs counter to the Piagetian stage theory. Furthermore, they maintain the current computer culture is biased toward a "formal" style and that this bias alienates women. Several case dialogues are offered as evidence as well as the fact that "of fifteen women, nine were concrete-style programmers, of fifteen men, four."

This kind of process analysis and theory building is virtually absent in the gender-computer literature to date, although it could be argued that Turkle and Papert are merely "story telling," as opposed to truly developing a viable theory. Perhaps a more accurate analysis is that they have generated partially supported and coordinated ideas. Whether we call it convincing story telling or theory, Turkle and Papert's research is a definite breakthrough in terms of providing a plausible explanation of gender-differentiated behavior with respect to programming. The information is alive, connected, and explanatory.

Conclusion

The rationale for a change in metaphors, namely, from a construct-oriented to a process-oriented metaphor to examine computer use, is presented. Paralleling this change in metaphor is a change in data collection technique from a paper-and-pencil approach to the use of think-aloud protocols. Through the use of think-aloud data we can begin to understand the process of computer-related behavior. In addition, a "contextual module" is advocated for interpreting verbal reports. It is speculated that the data from this investigation could form the building blocks for more effective and holistic instructional strategies for using computers. Preliminary results are encouraging, albeit sparse.

References

- Bereiter, C. (1985). Toward a solution of the learning paradox. *Review of Educational Research*, 55(2), 201-226.
- Bereiter, C. Aspects of Educational Learning Theory. *Review of Educational Research*, (in press).
- Ericsson, K. A. & Simon, H. A. (1980). Verbal reports as data. *Psychological Review*, 87(3), 215-251.
- Ericsson, K. A. & Simon, H. A. (1984). *Protocol analysis: Verbal reports as data*. Cambridge, MA, MIT Press.
- Kay, R. (1986). The effectiveness of attitudes, literacy, locus of control and gender in predicting commitment to the use of computers. Masters Thesis, Ontario Institute for Studies in Education, 22(6), 307-316.
- Kay, R. (1989a). Gender differences in computer attitudes, literacy, locus of control and commitment. *Journal of Research on Computing in Education*, 22(6), 307-316.
- Kay, R. (1989b). A practical and theoretical approach to assessing computer attitudes: The computer attitude measure (CAM). *Journal of Research on Computing in Education*, 22(4), 456-463.
- Kay, R. (1990a). Predicting student teacher commitment to the use of computer. *Journal of Educational Computing Research*, August.
- Kay, R. (1990b) The relation between computer literacy and locus of control. *Journal of Educational Computing Research*, 22(4), 464-474.
- Kay, R. PART II—Understanding gender differences in computer attitudes, aptitude and use: An invitation to build theory (submitted for publication).
- Keating, D. P. (1989). *Developmental processes in the socialization of cognitive structures*, Unpublished Manuscript.
- Turkle, S., & Papert, S. (1990, Autumn). Epistemological pluralism: Style and voices within the computer culture. *Signs*, 16 (1), pp. 128-157.

About the Author

Robin H. Kay is currently pursuing a Ph.D. in Educational Psychology at the Ontario Institute for Studies in Education (O.I.S.E.), at the University of Toronto. He earned a B.S. in Psychology at the University of Toronto, and an M.A. in computer applications in education at the University of Toronto.

His recent publications include:

- Kay, R.H. (1989). A practical and theoretical approach to assessing computer attitudes: The Computer Attitude Measure (CAM). *Journal of Research on Computing in Education*, 21 (4), 456-463.
- Kay, R.H. (1989b). Bring computer literacy into perspective. *Journal of Research on Computing in Education*, 22 (1), 35-47.
- Kay, R.H. (1990a). The relation between computer literacy and locus of control. *Journal of Research on Computing in Education*, 22 (4), 464-474.
- Kay, R.H. (1990b). Predicting student teacher commitment to the use of computers. *Journal of Educational Research*, 6 (3).

His recent activities include: a presentation on children's attitudes toward computers at the World Conference on Computers in Education (July 1990, Sydney, Australia); a two-part detailed analysis of gender differences in behavior toward computers; a cognitive analysis of individual strategies used to acquire computer-related concepts and skills; and a study at the University of California in Fresno designed to assess the computer-related attitudes and abilities of students.

He is also continuing to develop his scales on computer attitudes, ability, and locus of control, incorporating contextual factors into the scale. He is analyzing data from almost 700 students from universities in rural and urban Ontario, Canada.

II. THE RESEARCH FINDINGS

Gender Differences in Human-Computer Interaction

Charles W. Huff
St. Olaf College

John H. Fleming
University of Minnesota

Joel Cooper
Princeton University

Abstract

In this paper, we review a research program that has investigated the social psychology of human-computer interaction. This research has confirmed that there are recognizable differences in the ways that males and females approach the task of computing, and more surprisingly, differences in the ways in which computer software approaches men and women. We have found: 1) program designers' gender-based expectations can be reflected in the programs they design; 2) these programs can produce differential situational stress in users, depending upon gender; 3) that females have different opinions from males about their experience with and ability to use computers. In addition, women, particularly those with little computing experience, explain their computing performance differently than do men. Men are more self-serving in their explanations of performance, and more likely to take failure lightly. There is even some data that suggests that women may view and experience the computer in a different way than do men. All these differences affect performance and willingness to continue with computing. However, many of these effects are found only in those who were doing their computing in public and who had little experience with computers. Many gender differences disappear when we account for the effect of computing experience, but some gender differences appear to be ingrained deeply and subtly in our society.

The Social Basis of Gender Differences in Human-Computer Interaction

There is ample evidence that computing is a predominantly male practice (Markoff, 1989; Fennema, 1984; Fennema & Sherman, 1977; Linn, 1985; Lockheed, 1985; Lockheed, Nielson, & Stone, 1985). This male prevalence in the world of computing has concerned computer science professionals (Bernstein, 1990; Martin, 1990), educators (Gilliland, 1984; Taylor, 1980), and social science researchers (Chen & Paisley, 1985; Lepper & Gurtner, 1989). Not surprisingly, examples of the gender bias in computing are numerous and well documented. Among these findings, for instance, boys are more enthusiastic about computers than are girls (Nelson and Cooper, 1987), and boys tend to dominate computer courses, computer clubs, and

computer laboratories (Hess & Miura, 1985). There was a surge of women enrolling as computer science majors in the late 1970s, but that trend has slowed and women are again outnumbered in computer science courses (Martin, 1990). Women in business tend not to occupy influential positions in technology (Kraft & Dubnoff, 1986), and when they are associated with technology, it is usually in a "word processing ghetto" (Gutek & Bikson, 1985; Iacono & Kling, 1984; National Research Council, 1987).

One frequently cited observation about the gender imbalance is that women who are introduced to computers often voluntarily withdraw (Keisler, Sproull, & Eccles, 1985; Turkle, 1984). Of course, anyone confronted with the alien task of interacting with a machine may consider withdrawing (Fleming & Huff, 1989), but women more often seem to lack the enthusiasm that would keep them involved, even after reaching some level of competence (Nelson & Cooper, 1987). If they then attribute their withdrawal to a stable, internal disposition ("I'm not good at this"), it is likely to be permanent—effectively excluding that person from the educational and employment opportunities that computing skill affords.

The Social Nature of HCI

An important aspect of our approach to understanding these inequities is the recognition that human-computer interaction (HCI) does not occur in a social vacuum: the stereotypes and expectations of others, and even the mere presence of others, has been shown to affect the quality of HCI (Cooper, Hall, & Huff, 1990; Huff & Cooper, 1987; Robinson-Staveley & Cooper, 1990). Any comprehensive model of HCI will need to take these factors into account. Unfortunately, recognition of the social nature of HCI has been lacking in human-computer interaction research (Shneiderman, 1990).

This emphasis has led us to investigate gender stereotypes and gender differences as they are incorporated in the world of computing. For instance, we have examined how programmers' expectations about users affect the software they design, and how those designs affect the users' subsequent performance with that software.

On the basis of social psychological theories of human interaction (Word, Zanna, & Cooper, 1973), we predicted that program designers would design programs that reflected their gender-based expectations about the users of their programs. To test this hypothesis, we had teachers design educational software for either boys, girls, or (gender unspecified) "children" (Huff & Cooper, 1987). We then had the designers and independent raters rate those programs in terms of characteristics like time pressure, verbal interaction required, control given the user, etc. We found that programs designed for boys looked like games (with time pressure, eye-hand coordination, and competition most important), while programs for girls looked like "tools" for learning (with conversation and goal-based learning). As we anticipated, programs designed for "children" looked just like those designed for boys, confirming the existence of gender-based stereotypes in the design of educational software. Programs designed for "students in general" were really programs designed for boys. Interestingly, 80% of our program designers were female, many of whom expressed concern

that educational software was male-biased. Thus, our gender stereotypes are subtly and strongly woven into software, even by well-meaning, female educators.

But do these differences in program design actually result in different outcomes for students using the programs? In order to test this, we chose female- and male-oriented programs according to criteria corroborated by the Huff and Cooper (1987) research (Cooper, Hall, & Huff, 1990). The male-oriented program involved competition and shooting, whereas the female-oriented program used music, verbal feedback, and tasks that required completion. Middle school students then used these mathematical programs in both a private (isolated individual carrel) and a public (computer lab) setting. We found that students using software designed for the other gender reported more situational stress than when using gender appropriate software. However, this cross-gender software-induced stress occurred only when the software was used in the public setting. When the software was used in private there were no differences in situational stress levels. Thus we found the cross gender stress effect we had anticipated, but discovered that it was linked to public performance.

The fact that the cross-gender stress effect only occurred in public emphasizes even more strongly the social nature of human-computer interaction. Thus, one social context of computing is provided by the designer of the Gender Differences in Human-Computer Interaction Program, but another important social influence on computing comes from the situation in which the person uses the software.

Mere Presence, Arousal, and Social Comparison

In an attempt to understand these public performance effects, Robinson-Staveley and Cooper (1990) conducted two studies to examine the effect of other people's presence on performance in a computing task. They found that when women used a computer in the presence of another person, they reported higher levels of situational stress and performed less well than when they did the same task in private. In contrast, when men completed the computer task in public, they performed better and reported significantly lower levels of situational stress than they did in private. Both these effects occurred only among computing novices; irrespective of gender, experts were unaffected by the presence of others.

A second study proposed an explanation for this effect: perhaps the gender differences in reaction to the presence of others were mediated by expectations of success or failure. In the second study, men and women were asked to do the same computer task in either public or private, but some were told that the task would be very difficult for them. Others were told that the task would be quite easy for them. No gender differences or instructional set differences occurred when the task was done alone (replicating our first study, and Cooper, Hall, and Huff, 1990). In addition, no gender differences were found in the public condition. However, differences were found in the public performance condition based on expectations. Those expecting success performed better in public than in private, whereas those expecting failure performed worse in public. Thus, the second study was able to eliminate the public performance gender difference by manipulating expectations of success or failure.

This suggests (but is clearly not conclusive proof) that the gender differences are, in fact, a function of expectancies. Perhaps when an individual expects failure—and there are others present to witness this failure—arousal is produced that interferes with performance. This arousal hypothesis has the advantage of support from current research (Baumeister, 1984; Baumeister et al., 1985) and also may explain the improved performance of those expecting success—the arousal produced by the presence of others facilitates performance by providing motivation.

Interaction Expectations

In research focussed on the individual's *experience* of computing, we have collected evidence that suggests that women may think about their interactions with computers in different ways than do men. In a preliminary study (Wilder, Mackie, & Cooper, 1985), male and female elementary school students completed a questionnaire in which they provided descriptions of computers. In general, both boys and girls described computers as "masculine" objects—they attributed more masculine and fewer feminine traits to computers. By inference, this finding suggests that people may approach interactions with computers as though the machines possessed masculine characteristics or were "male."

Research by Cooper and Hall (in press) has revealed a suggestive gender difference in the human-like or mechanical attributions made to a computer. Cooper and Hall asked college aged students to write essays about success and failure experiences with a computer. These essays were then coded for the extent to which the computer was described in psychological terms ("it accepted my program and assured me that it was correct") or mechanical terms ("this should register into the computer"). Not surprisingly, they found that the computer was described in more psychological terms when students were relating a failure—just as we get mad at our cars when they won't start. They also found an interesting gender difference that was independent of success and failure: there were no language differences among novices in reference to the computer, but women who were more experienced with the computer referred to it in more mechanical terms, while men who were more experienced referred to the computer in more psychological terms. Thus, to experienced women, the computer was an object, a tool, while to experienced men the computer was more like an active interactant—it "did" things and "responded." The full essays indicate that the men were not naively anthropomorphizing the machine, but were just talking about it in a way different from the way experienced women did. This suggests that there may be some difference in the way that men and women experience human-computer interaction.

Gender Differences in Assessment

In addition to finding differences in performance with and perception of computers, we have also documented gender differences in assessment of computing performances. For instance, Nelson and Cooper (1987) focused on children's reactions to computer experiences. Male and female fifth graders were asked to use a

computer program to complete very easy anagrams (like "bkoo"). For some of them, the program paused four times for 15 seconds during the session and showed the message "Please WAIT for the next question." For others, identically placed pauses showed "error" messages on the screen that were unrelated to the anagram task (such as "**&^%\$bus error: core dumped! ! WARNING on DRIVE 7888*9x0"). The question of interest here was: how will program users assess the causes of these "errors"?

After using the "error" program, girls felt that they were not as good at computers as others.¹ In contrast, males were more enthusiastic and felt they were better at computers than others after the task, irrespective of the program they used. Thus, males had the attributional resources to allow them to continue with computing even through failure, whereas women took failure at these tasks personally.

When Nelson and Cooper statistically removed the effect of prior experience with computers from their analysis, they found that the attributional differences were reduced. This is reasonable, given that girls in the sample reported using computers less frequently and having less access to computers. Perhaps, with more exposure to and experience with computers, these differences in attribution of failure could be eliminated. However, Wilder, Mackie, and Cooper (1985) report that among entering college students they surveyed, women who had computing experience equal to men (in terms of languages known, years of practice, etc.), nonetheless *felt* less experienced than those men.

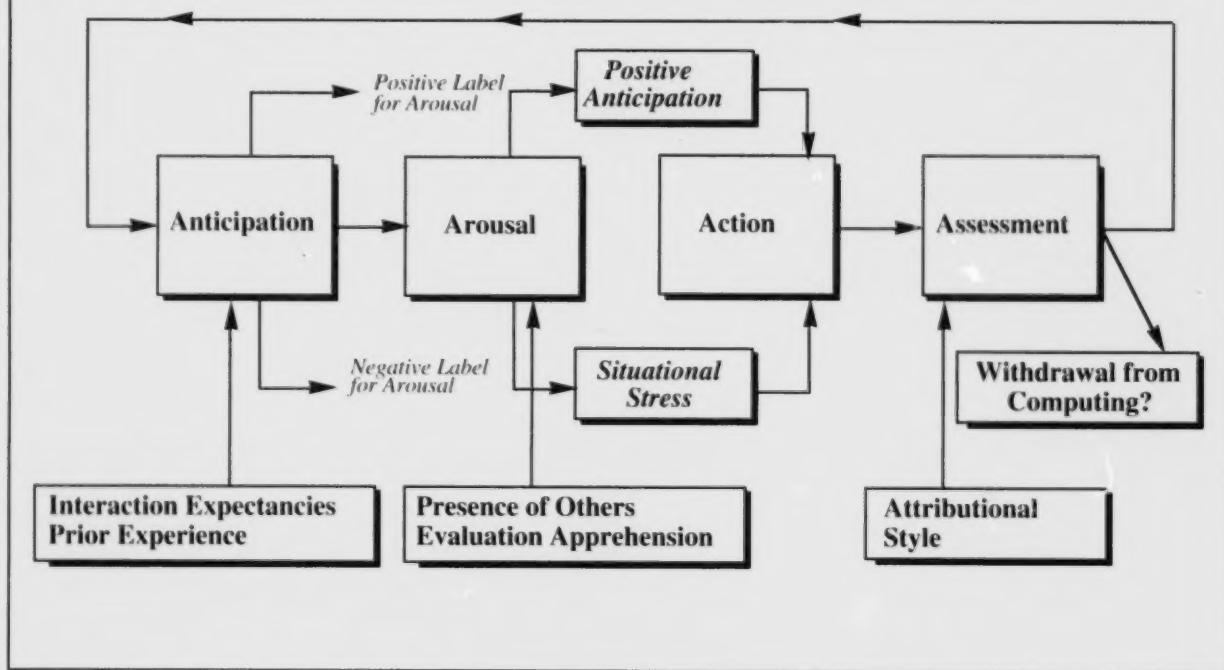
A Model of Computing Performance

In our attempt to shape a coherent story about the research we have reviewed here, we have developed a model of computer use similar in design to, but broader in scope than, those used by cognitive researchers in human-computer interaction (Norman, 1986). The model we propose is based on a four-step cycle of anticipation, arousal, action, and assessment and is presented graphically in Figure 1. This model is implicit in most of the "choking" and withdrawal literature (Baumeister, 1984; Baumeister et al., 1985) and is also closely related to the attributional models of Weiner and his colleagues (Weiner, 1974; Weiner et al., 1972).

Anticipation—The model begins with anticipation of the performance and the evaluative situation. People are motivated to control and predict their environment (Bandura & Adams, 1977), and are thus likely to form expectations about the computing situation, the interaction with the computer, their personal abilities, the probability of success, the likelihood of evaluation, and a host of other parameters about any upcoming HCI performance. This anticipation may be explicit or covert, but it allows the actor to prepare for the performance situation.

¹ Nelson and Cooper (1987) were careful to disabuse all participants of any concern that they might not be "good at computing" after they had finished the study. Comments during the debriefing indicate that they were successful. Manipulations like this are sometimes necessary in order to determine carefully the relationships among variables. We expect that differences in attribution might have been harder to come by (and harder to believe) if we had merely asked "If you had failed, how would you explain it?"

Figure 1.
The 4A Model of Human-Computer Interaction and Performance



Arousal—Depending upon the outcome of the individual's search and analysis in the anticipation step, anticipation can manifest itself either as situational stress or as positive anticipation (or some mix of the two). In the model's terms, situational stress or positive anticipation both refer to arousal that is negatively or positively labeled, respectively. This arousal results primarily from the presence of others, although undifferentiated arousal produced by extraneous sources (such as concern over impending evaluation, or an expectation of failure) can magnify the effects of whatever arousal has been produced directly during this stage.

Preliminary studies have indicated that interacting with a computer in a public context significantly increases situational stress and affects performance, whereas private performance reduces situational stress. We expect that in addition to the arousal caused directly by the presence of others, concern about possible evaluation by others is one way that the presence of others may affect anticipation (Cooper, Hall, & Huff, 1990; Robinson-Staveley & Cooper, 1990). Thus, the presence of others may contribute to the production of arousal in both the anticipation and arousal stages.

Action—Valence-labelled arousal is important in determining the actions that the individual chooses and the quality of the performance of the chosen action. Apprehension can not only distract the actor causing him or her to "choke," but also may even lead the actor to withdraw effort, "taking a fall" or withdrawing (Baumeister, 1984). On the other hand, confidence may not be distracting and may even facilitate a user's performance (Baumeister et al., 1985).

Assessment—Even if confident users do not succeed in their performance, their confidence may shape the assessment of the failed performance. If, after the attribution process, the causal locus for the failure is considered unstable, the user may be willing to try again. At the assessment stage, gender differences in attributional style (Dweck, 1978; Dweck, Goetz, & Strauss, 1980; Dweck, 1980; Frieze, 1975) can influence the individual in determining if the performance was a success or a failure and in laying blame for the outcome. This assessment will, in turn, influence whatever anticipation the individual may form for additional tasks.

This is a model of a cyclical process. As the cycle moves from assessment back to the initial step of anticipation, it can produce a self-sustaining spiral of optimism or pessimism. Weiner (1974) has shown that after success or failure at a task, goal expectancies will change and that the causal attributions for that success or failure will determine the direction or degree of shift in expectancy. For those who are apprehensive and inclined toward pessimism, this reassessment may create a trap that can lead to withdrawal from the field.

Variables Affecting the Performance Cycle

There are a variety of individual and situational variables that affect the performance cycle in HCI. We present several that we have investigated in Figure 1. In addition, Figure 1 points out a number of influences and processes for which we have no current evidence, but plan to investigate in the near future. For the sake of simplicity, we assign each variable to one step in the performance cycle. In practice,

however, variables may affect more than one step, and perhaps even all of them.

Prior experience—Novices seem to be the ones who are both more anxious when using computers and who are more affected by the manipulations we have used in our studies (Robinson-Staveley & Cooper, 1990). This is in part because they have less facility with the computer, but we expect that it is also because they do not yet have a stable expectation about what HCI involves. As novices gain experience, they also gain a store of explanations for their performance that may allow them to be more sanguine when assessing failure.

Gender-based interaction expectancies—We, as well as several other researchers, have hypothesized that individuals initially use human-human interaction as a model on which to build their expectations for HCI (Bench-Capon & McEnery, 1989; Fleming & Huff, 1989; Hauptmann, 1987; Orcutt & Anderson, 1977; Quintanar, Crowell, Pryor, & Adamopoulos, 1982). That is, novice users may enter the HCI arena with generalized expectations about interactions with computers that are closely tied to their prior experiences and expectations of interacting with people.

A large body of research on human-human interaction suggests that women employ (and presumably prefer in response) interaction styles that are less dominant and more pleasant (Maccoby & Jacklin, 1974)—styles that include more eye contact, approach cues (such as smiling, touching and being touched, gesturing, and physical proximity) (Exline, 1963; Exline & Winters, 1965; Frances, 1979; Hall, 1984; Jourard, 1966; Mehrabian, 1971, 1972), less relaxation, and more submissiveness (Mehrabian, 1969, 1971, 1972). In other words, females' implicit interaction styles can be described as more expressive, animated (in terms of hand gestures and facial feedback), and "immediate" than males'. In contrast, males seem content with interactions that are generally less expressive, and they seem to prefer constrained interaction styles.

Current computer interfaces can be reasonably described as primarily direct, impolite (Brown & Levinson, 1987), and nonexpressive. Consequently, because the computer's "interaction style" does not provide the sorts of cues that females typically use to organize and understand their interactions, their interactions with the computer may be perceived as more difficult and substantially less pleasant (for a more detailed consideration of these issues in human-human interaction, see Maccoby, 1990).

In summary then, males may think of HCI as more of a "real" interaction. They may think that the nonexpressive computer is a reasonable pseudo-interaction partner, whereas women seem to think of HCI as more just "using a tool." Women may not regard the computer as an interactant at all, and may, therefore, feel less attached to it. These differences in construing HCI may be at the base of the differences in attribution to the computer that Cooper and Hall (in press) found. They may also lead to different expectations about what HCI is really like, and over time this differentiation between males and females could foster or further exacerbate the gender bias evident at other points in our model.

This hypothesis of a gender difference in the experience of HCI presently can

support no concrete recommendations about the types of interfaces that may change these experiences, making them more equal. It is even difficult to say that the experiences *should* be made more similar, or to say whose style of experience should be changed. Clearly, we are just in the beginning stages of investigating this phenomenon.

Gender differences in the assessment stage—Several researchers have found gender-based differences in attributional style (Frieze, 1975), an individual difference that may affect the assessments that people make of their performance with the computer. That is, males tend to take credit for successful outcomes, whereas females have been shown to be less self-enhancing. Such a difference in attributional styles may explain why males who initially fail at a computer task are not stymied by such failure, whereas females who fail are. Conversely, it would also account for why females who succeed nonetheless maintain an anticipation of failure in the face of successful performance. Thus, if men attribute success and failure in a more self-enhancing manner than do women, men may be able to sustain interaction with the computer long enough to experience real success.

Conclusions

By bringing this model to bear on HCI, we are explicitly including social psychological concerns in HCI research, a focus that has been almost completely lacking in earlier work (Nickerson, 1986; Shneiderman, 1990). The arguably myopic focus on the purely cognitive aspects of HCI has led those who design and implement software away from considering the very factors that may contribute to the gender bias in computing. We hope to identify specific factors that precipitate the decision by many women to withdraw from computing (Kiesler & Sproull, 1987). Most programs attempting to redress this inequity now use a scattershot approach, trying everything in the hope that something will work (Gilliland, 1984; Klein, 1989). This research may help us focus on those factors that can be shown to affect women negatively (also see National Research Council, 1987). If these issues are not brought to those who can effect a change in computing, or if they are not considered in the development and implementation of software, systems, interfaces, and computing environments, it is likely that computing will continue to remain a male preserve.

References

- Bandura, A., & Adams, N.E. (1977). Analysis of self-efficacy theory of behavioral change. *Cognitive Therapy and Research*, 1, 287-308.
- Baumeister, R. F. (1984). Choking under pressure: Self-consciousness and paradoxical effects of incentives on skillful performance. *Journal of Personality and Social Psychology*, 46, 610-620.
- Baumeister, R. F., Hamilton, J., & Tice, D. (1985). Public versus private expectancy of success: Confidence booster or performance pressure? *Journal of Personality and Social Psychology*, 48, 1447-1457.

- Bench-Capon, T.J.M., & McEnery, A.M. (1989). People interact through computers, not with them. *Interacting with Computers*, 1, 31-38.
- Bernstein, D. L. (1990). In search of gender-free paradigms for computer science education: A new introduction to computer science. Paper presented at C. D. Martin (Chair), *Gender-free paradigms for computer science education*. Workshop conducted at the National Educational Computing Conference, Nashville.
- Brown, P., & Levinson, S. (1987). *Politeness: Some universals in language usage*. Oxford: Oxford University Press.
- Chen, M., & Paisley, W. (Eds.). (1985). *Children and microcomputers: Research on the newest medium*. Beverly Hills, CA: Sage.
- Cooper, J., & Hall, J. (in press). Gender, experience, and attributions to the computer. *Journal of Educational Computing Research*.
- Cooper, J., Hall, J., & Huff, C. W. (1990). Situational stress as a consequence of sex stereotyped software. *Personality and Social Psychology Bulletin*, 16, 419-429.
- Dweck, C. S. (1978). Sex differences in learned helplessness. *Developmental Psychology*, 14, 268-276.
- Dweck, C. S. (1980). Motivational processes affecting learning. *American Psychologist*, 41, 1040-1048.
- Dweck, C. S., Goetz, T. E., & Strauss, N. L. (1980). Sex differences in learned helplessness: IV. An experimental and naturalistic study of failure generalization and its mediators. *Journal of Personality and Social Psychology*, 38, 441-452.
- Exline, R. V. (1963). Explorations in the process of person perception: Visual interaction in relation to competition, sex, and need for affiliation. *Journal of Personality*, 31, 1-20.
- Exline, R. V., & Winters, L. C. (1965). Effective relations and mutual glances in dyads. In S. S. Tomkins and C. E. Izard (Eds.), *Affect, cognition, and personality* (pp. 319-330). New York: Springer-Verlag.
- Fennema, E. (1984). Girls, women, and mathematics. In E. Fennema and M. J. Ayer (Eds.), *Women and education* (pp. 137-164). Berkeley, CA: McCutcheon.
- Fennema, E., & Sherman, J. (1977). Sex related differences in mathematical achievement, spatial visualization, and affective factors. *American Educational Research Journal*, 14, 51-71.
- Fleming, J. H., & Huff, C. W. (1989, August). A social basis for rules of human-computer interaction. Paper presented at the annual meeting of the American Psychological Association, New Orleans, LA.
- Frances, S. J. (1979). Sex differences in nonverbal behavior. *Sex Roles*, 5, 519-535.
- Frieze, I. H. (1975). Women's expectations for and causal attributions of success and failure. In M. Mednick, S. S. Tangri, and L. W. Hoffman (Eds.), *Women and achievement*. Washington, D.C.: Hemisphere Publishing.
- Gilliland, K. (1984). EQUALS in computer technology. *The Computing Teacher*, 4, 42-44.
- Gutek, B. A., & Bikson, T. K. (1985). Differential experiences of men and women in computerized offices. *Sex Roles*, 13, 123-136.

- Hall, J. A. (1984). *Nonverbal sex differences*. Baltimore, MD: Johns Hopkins University Press.
- Hauptmann, A. (1987). *Talking to computers: An empirical investigation*. Unpublished manuscript, Massachusetts Institute of Technology.
- Hess, R. D., & Miura, L. T. (1985). Gender differences in enrollment in computer camps and classes. *Sex Roles*, 13, 193-203.
- Huff, C., & Cooper, J. (1987). Sex bias in educational software: The effect of designers' stereotypes on the software they design. *Journal of Applied Social Psychology*, 17, 519-532.
- Iacono, S., & Kling, R. (1984). Office routine: The automated pink collar. *IEEE Spectrum*, 21, 73-76.
- Jourard, S. M. (1966). An exploratory study of body-accessibility. *British Journal of Social Clinical Psychology*, 5, 221-231.
- Kiesler, S., Sproull, L., & Eccles, J. S. (1985). Pool halls, chips, and wargames: Women in the culture of computing. *Psychology of Women Quarterly*, 9, 451-462.
- Klein, S. S. (1989). *Handbook for achieving sex equity through education*. Baltimore: Johns Hopkins University Press.
- Kraft, P., & Dubnoff, S. (1986). Job context, fragmentation, and control in computer software work. *Industrial Relations*, 25, 184-196.
- Lepper, M., & Gurtner, J. (1989). Children and computers: Approaching the twenty-first century. *American Psychologist*, 44, 170-178.
- Linn, M. C. (1985). Fostering equitable consequences from computer learning environments. *Sex Roles*, 13, 229-240.
- Lockheed, M. (1985). Women, girls, and computers: A first look at the evidence. *Sex Roles*, 13, 115-122.
- Lockheed, M. E., Nielson, A., & Stone, M. K. (1985). Determinants of microcomputer literacy in high school students. *Journal of Educational Computing Research*, 1, 81-96.
- Maccoby, E. E. (1990). Gender and relationships. *American Psychologist*, 45, 513-520.
- Maccoby, E. E., & Jacklin, C. N. (1974). *The psychology of sex differences*. Stanford, CA: Stanford University Press.
- Markoff, J. (1989, February 13). Computing in America: A masculine mystique. *The New York Times* (pp. A1, B10).
- Martin, C. D. Gender-free paradigms for computer science education. *Computing Research Newsletter*, Oct., 1990.
- Mehrabian, A. (1969). Significance of posture and position in the communication of attitude and status relationships. *Psychological Bulletin*, 71, 359-372.
- Mehrabian, A. (1971). Verbal and nonverbal interaction of strangers in a waiting situation. *Journal of Experimental Research in Personality*, 5, 127-138.
- Mehrabian, A. (1972). *Nonverbal communication*. New York: Aldine-Atherton.
- Mehrabian, A. (1981). *Silent messages: Implicit communication of emotions and attitudes* (2nd. ed.). Belmont, CA: Wadsworth.
- National Research Council. (1987). *Computer chips and paper clips: Technology and women's employment* (Vol. 1). Washington, DC: National Academy Press.

- Nelson, L., & Cooper, J. (1987). *Children's reactions to success and failure with computers*. Manuscript under review.
- Nickerson, R. S. (1986). *Using computers: Human factors in information systems*. Cambridge, MA: MIT Press.
- Norman, D. A. (1986). Cognitive Engineering. In D. A. Norman & S. W. Draper (Eds.) *User Centered System Design*. (pp. 31-62). Hillsdale, NJ: Lawrence Erlbaum.
- Orcutt, J. D., & Anderson, R.E. (1977). Social interaction, dehumanization, and the "computerized other." *Sociology and Social Research*, 61, 380-397.
- Quintanar, L.R., Crowell, C. R., Pryor, J. B., & Adamopoulos, J. (1982). Human-computer interaction: A preliminary social psychological analysis. *Behavior Research Methods and Instrumentation*, 14, 210-220.
- Robinson-Staveley, K., & Cooper, J. (1990). Mere presence, gender, and reactions to computers: Studying human-computer interaction in the social context. *Journal of Experimental Social Psychology*, 26, 168-183.
- Shneiderman, B. (1990). Human values and the future of technology: A declaration of empowerment. In R. E. Anderson & C. D. Martin (Eds.) *Proceedings of the Conference on Computers and the Quality of Life* (pp. 1-6). New York, Association for Computing Machinery.
- Taylor, R. P. (1980). *The computer in the school: Tutor, tool, tutee*. New York: Teacher's College Press.
- Turkle, S. (1984). *The second self*. New York: Simon and Schuster, Inc.
- Weiner, B. (1974). *Achievement motivation attribution theory*. Morristown, NJ: General Learning Press.
- Weiner, B., Frieze, I., Kukla, A., Reed, L., Rest, S. & Rosenbaum, R. M. (1972). Perceiving the causes of success and failure. In E. E. Jones, D. E. Kanouse, H. H. Kelley, R. E. Nisbett, S. Valins, & B. Weiner (Eds.), *Attribution: Perceiving the causes of behavior*. Morristown, NJ: General Learning Press.
- Wilder, G., Mackie, D. M., & Cooper, J. (1985). Gender and computers: Two surveys of computer-related attitudes. *Sex Roles*, 13, 215-228.
- Word, C. O., Zanna, M. P., & Cooper, J. (1973). The nonverbal mediation of self-fulfilling prophecies in interracial interaction. *Journal of Experimental Social Psychology*, 10, 109-120.

About the Authors

Charles W. Huff is an assistant professor of psychology at St. Olaf College in Northfield, Minnesota. He earned a Ph.D. in Social Psychology at Princeton University, an M.A. in Psychology at Princeton University, an M.A. in Psychology at the College of William & Mary, an M.A. in Philosophy at the University of South Florida, and a B.S. in Psychology at Georgia Southern College.

His recent publications include:

- Huff, C.W. & Cooper, J. (1987). Sex bias in educational software: The effects of designers' stereotypes on the software they design. *Journal of Applied Social Psychology*, 17, 519-532.

- Huff, C.W. & Rosenberg, J. (1989). The online voyeur: The promises and pitfalls of electronic interaction. *Behavior Research Methods, Instruments, and Computers*, 21, 166-172.
- Huff, C.W., Sproull, L. & Kiesler, S. (1989). Computer communication and organizational commitment: Tracing the relationship in a city government. *Journal of Applied Social Psychology*, 29, 181-188.
- Hall, J., Cooper, J. & Huff, C.W. (1990). Situational stress as a consequence of sex-stereotyped software. *Personality and Social Psychology Bulletin*, 16, 419-429.
- Huff, C.W. & Dickson, J.F. (In press). Finding stable support for computing in psychology: Lessons from innovation diffusion in organizations. *Behavior Research Methods, Instruments, and Computers*.

His recent presentations include: *Choosing and designing for an audience*, an invited workshop at IBM, Rochester, MN; *Establishing educationally productive teaching laboratories*, A symposium conducted at the Society for Computers in Psychology, New Orleans; *Tools for assessing the impact and use of computer systems*, workshop conducted at the Computers and the Quality of Life conference, Washington, D.C.; Expectations and gender differences and in computer use. In S. Turkle (chair), *The Head and the Heart: Gender aspects of computing*, plenary panel conducted at the Computers and the Quality of Life conference, Washington, D.C.; *Programmer prototypes of the user: Who is this program written for anyway?*, talk given at Bell Laboratories, Murry Hill, NJ.

John H. Fleming is an Assistant Professor of Psychology at the University of Minnesota. He earned a B.A. in Psychology at the College of William & Mary, an M.A. in Psychology at Princeton University, and a Ph.D. in Social Psychology at Princeton University.

His recent publications include:

- Fleming, J.H., Darley, J.M., Hilton, J.L. & Kojetin, B.A. (1990). Multiple audience problem: A strategic communication perspective on social perception. *Journal of Personality and Social Psychology*, 58, 593-609.
- Fleming, J.H. & Darley, J.M. (1990). The purposeful-action sequence and the "illusion of control": The effects of foreknowledge and target involvement on observers' judgement of others' control over random events. *Personality and Social Psychology Bulletin*, 16, 347-358.
- Fleming, J.H. & Darley, J.M. (in press). Mixed messages: The multiple audience problem and strategic communication. *Social Cognition*.
- Fleming, J.H. (in press)...Well that depends on what you mean by "boundary spanning...": On the art of equivocation and other varieties of tactical communication. [Review of J.B. Bavelas, A. Black, N. Chovil, & J. Mullett, *Equivocal communication*; and M.J. Cody & M.L. McLaughlin (Eds.), *The psychology of tactical communication*.] *Contemporary Psychology*.
- Fleming, J.H. (in press). The hostage dilemma: Communicating truth through

falsehood. In J.H. Fleming & C. DuFour, Instructor's manual for S. Worchel, J. Cooper, & G.R. Goethals's, *Understanding Social Psychology* (5th ed.). Pacific Grove, CA: Brooks/Cole.

His major research interests are: tactical aspects of strategic communication and self-presentation; social perception and attribution; social interaction and interpersonal expectancy effects; and the social psychology of human-computer interaction.

Joel Cooper is currently at Princeton University. He earned his B.A. at the City College of New York, and his Ph.D. at Duke University.

His recent publications include:

Cooper, J. & Huff, C. (1987). Sex bias in educational software: The effect of designers' stereotypes on the software they design. *Journal of Applied Social Psychology*, 17, 519-532.

Cooper, J. & Mufson, L. (1989, Sept./Oct.). Factors associated with underachievement in seventh grade children. *Journal of Educational Research*, 83 (1), 5-10.

Cooper, J. & Robinson-Staveley, K. (1990). The use of computers for writing: Effects on an English composition class. *The Journal of Educational Computing Research*, 6 (1), 41-48.

Cooper, J., Hall, J. & Huff, C. (1990). Situational stress as a consequence of sex stereotyped software. *Personality and Social Psychology Bulletin*, 16 (3), 419-429.

Cooper, J. & Robinson-Staveley, K. (1990). Mere presence, gender and reactions to computers: Studying human computers interaction in the social context. *Journal of Experimental Social Psychology*, 26, 168-183.

Cooper, J. & Hall, J. (1991). Gender, experience, and attributions to the computer. *Journal of Educational Computer Research*, 7 (1).

Cooper, J., Nelson, L., & Wiese, G. (1991, March). Getting started with computers: Experience, anxiety and relational style. *Computers in Human Behavior*.

His research interests are the social psychology of computer anxiety, and issues involved in attitude change. In the area of computer anxiety, he is conducting research on the basis of gender differences in reactions to the computer.

Author Note

The authors are indebted to those who have worked with them on this research including Kristine Robinson-Staveley, Lori Nelson, and Joan Hall. The McDonnell Foundation supported much of the research reviewed here. Requests for reprints should be sent to: Charles Huff, Department of Psychology, St. Olaf College, Northfield MN, 55057.

Gender and Attitude Toward Computers

James R. Aman, Ph.D.

Wilmington College, Wilmington, OH

Background

By 1985 the downtrend in computer science enrollment at the college level was very apparent. Participation of women had never been particularly good, and their percentage dropped proportionately as the trend continued. Researchers of gender equity issues probed many areas for probable causes. Building on their work, pre-college patterns of computer use and perceptions of computers were the broad topic of the study reported here.

Published research suggested two broadly gender-appropriate computer applications: problem solving and written composition. The relations of several factors that might logically contribute to each of these, as well as to overall attitude toward the computer, were the focus of the study.

Conducted against a backdrop of hypotheses about social and academic factors, the research adopted Shaffer's thesis: regular exposure to an object accompanies the development of favorable attitudes toward the object (Shaffer, 1985). Given the dramatic expansion of computer use in all sectors of society over the past decade, negative attitudes toward computers could only inhibit performance in computer-related jobs. The majority of women in the business world were still holding traditional secretarial or clerk-level positions. Computerized word processing had simply supplanted more traditional typing and stenographic skills. There were warnings that lack of advanced computing skills could cause women to lose much of the ground gained in the work force since 1970 (*Online Today*, 1984).

Attitudes and perceptions of the sex-appropriateness of the computer form in the middle and high schools and are carried into adulthood. Schubert and Bakke warned that if the computer continued to be perceived as a mathematical, male-appropriate, problem solving tool, the percentages of females electing to take computer courses would continue to be small (Schubert & Bakke, 1984). The logical extension would be a decrease in the number of women in the computer science professions. Numerous studies had reported inequities in computer use and access both in and out of the classroom (Anderson, Welch, & Harris, 1984; Lockheed & Frakt, 1984; Miura & Hess, 1983; Schubert and Bakke, 1984). Increasing the amount of a person's computer experience had been suggested as a way of improving an individual's attitude about the computer (Fertsch, 1985). Indeed, because women see more product-oriented utility for the computer, they must have exposure to computers in non-mathematical contexts during the formative pre-college years (Kreinberg & Stage, 1983; Lockheed & Frakt, 1984; Rampy, 1983; Williams, Coulombe, & Lievrouw, 1983).

At least part of the differential attitudes of men and women about computers is due to our society's process of sexual stereotyping. Computers are considered a male sphere of influence and are avoided by women because of pre-existing habits of sex

segregation (Lockheed & Frakt, 1984). Furthermore, if both males and females want to use a computer, females tend to defer to males (Boss, 1982). Such attitudes are difficult, if not impossible, to reform. And in the absence of equitable computer education, schools will be unable to circumvent the stereotyping process.

Fisher suggested gender-segregated education as a means of reducing opposite-sex pressure on women to conform to standard, social sexual roles (Fisher, 1984). Whyte proposed all-female classes as a means of alleviating or eliminating gender inequities in the classroom (Whyte, 1984). These two themes were played out in numerous studies in the 1970s and early 1980s (Benz, Pfeiffer, & Newman, 1981; Boss, 1982; Cohen & Cohen, 1980; Fennema, 1980; Lockheed & Frakt, 1984; Maccoby & Jacklin, 1974; Serbin, 1983; Webb, 1984).

Although researchers repeatedly noted that females took passive roles in classrooms, Fennema suggested that educationally significant sex-related differences in mathematics performance would disappear if the time that both males and females spent studying the subject could be equalized (Fennema, 1980). Webb reported exactly that phenomenon in a later study (Webb, 1984). The implication for computer class participation is apparent: teacher interactions aside, equality of computer experience would provide a mechanism for alleviating or eliminating gender-related computer inequity (Aman, 1985).

Adolescent males and females also tend to socialize in small, usually same-sex, groups. To study the interaction patterns and achievement in small groups, one researcher constructed three sets of students: male majority, female majority, and equal numbered. The levels of achievement and interaction results were the same in the "equal" group. In the "female majority" group, females showed lower achievement than did males in the same group and directed most of their interaction to the males. Females in the "male majority" group were ignored by the males, who again showed the greater achievement. Overall, females were more responsive to requests of all group members for help, while males tended to help only other males. Females, the researcher concluded, may be less successful in obtaining *any* needed help in a mixed-sex group, but may be more successful in all-female groups (Webb, 1984). This study has implications for gender-segregated, or single-sex, education.

The Research Design

The general research question was: What are the relations between (a) gender, (b) highest level of mathematics course completed (or in progress), (c) amount of prior computer experience (coursework, programming, and word processing), (d) access to computers outside the school, (e) number of hours of weekly computer use, and (f) gender-segregated schooling and attitudes toward the use of the computer (1) in general, (2) as a tool for problem solving, and (3) as a tool for written composition. The six components, drawn from previous research, were considered the most likely factors for the attitudes. The attitudes were, respectively, non-gender-specific, male-specific, and female-specific, as suggested by published research.

The study was conducted on the campuses of two gender-segregated Catholic

high schools in a major metropolitan city in the southwestern United States. The schools are very similar in many respects. The campuses are contiguous. They are located in an upper-middle-class area where parents are able to provide their children with many experiences and opportunities not readily available in other sections of the same city. The schools maintain high academic standards in college preparatory environments and have earned reputations for producing students of high academic achievement. Some 96% of female graduates and 99% of male graduates pursue college studies.

The mean combined Scholastic Aptitude Test score in the all-female school was 950 (September, 1985), well above the national mean for females of 877 (College Entrance Examination Board, 1985). In the all-male school, the mean was 1049 (October, 1984) compared to a national mean of 936. Preliminary Scholastic Aptitude Test scores were similarly high.

Teaching staffs of the schools were also similar in composition. All 73 faculty members of the schools were certified or had completed enough hours in the assigned teaching field to obtain certification. Forty-seven faculty members held master's degrees and four had doctorates.

Mathematics and computer science requirements and course sequences were also similar. The computer lab at the all-female school was available before and after school and during lunch. Software supplementing the science, accounting, mathematics, and language arts was used. The all-male school reported a computer club as its only extracurricular computer activity.

The Sample

The sample for this study was 500 subjects randomly selected from 1250 students at the two schools. This represented approximately 40% of the responses from each grade level in each school. Although voluntary participation had been requested, the schools' administrators chose to have all students complete the questionnaires. To eliminate any possible contamination of responses across peer groups, classes, campuses, or families, the instrument was administered to all students during the same time period on the same day.

Frequency data for the demographic items on the questionnaire are presented in Table 1. They are presented with only a single comment. Inequity in all experiential categories except the number of courses completed is obvious. This single category is subject to curricular control. In the other, self-selected areas, there is a reflection of societal imprinting about computers.

The Instrument

The Fertsch Computer Attitude Measurement Questionnaire (FCAMQ) was originally intended for use in middle schools (Fertsch, 1985). With the cooperation of its original author, modifications were made to appropriate demographic items for the new study. The original form had been developed "with input from an expert panel consisting of a university professor experienced in instrument and research design and

Table 1
Demographics

	<i>Males</i>	<i>Females</i>
<i>Gender-Segregated Schooling</i>		
Less than 1 year	69	77
1 year	48	61
2 years	53	67
3 or more years	46	69
<i>Weekly computer use</i>		
None	104	196
1-3 hours	79	69
4-6 hours	18	15
7-10 hours	8	2
More than 10 hours	7	1
<i>Computer experience</i>		
None	22	54
Less than 6 months	59	90
6 months to 1 year	44	69
1-2 years	37	36
More than 2 years	54	35
<i>Programming experience</i>		
None	54	135
Some	111	110
A lot	50	38
<i>Word processing experience</i>		
None	104	155
Some	64	105
A lot	48	24
<i>Computer courses completed</i>		
None	45	116
1	120	119
2	41	40
3	6	4
4 or more	3	1

an elementary school computer education teacher" (Fertsch, 1985). At the time of use in this study, the instrument had been field tested with a total of 805 subjects. Computations of reliability yielded acceptable values.

The FCAMQ contained 13 demographic items and 42 attitudinal items in the form of simple statements. Likert-type responses to these statements indicated degrees of agreement with the statements ranging from "I strongly disagree" at the low end to "I strongly agree" at the high end. Some items were stated negatively.

Table 2
Correlations of Independent Variables with Attitudes

	<i>General</i>	<i>Problem Solving</i>	<i>Writing</i>
Problem solving attitude	.72***		
Writing attitude	.53***	.69***	
Grade level	.06	.00	.03
Age	.05	.00	.02
Gender-segregated education	.04	-.03	.01
Mathematics attainment	.08	.06	.05
Computer experience	.29***	.22***	.25***
Access	.16**	.18***	.22***
Courses	.14*	.12*	.06
Hours	.29***	.21***	.21***
Programming	.26***	.21***	.24***
Word processing	.22***	.14*	.24***

* < .01

** < .001

*** < .0001

Data analyses included a correlational analysis among all variables in the study, yielding information about the strengths of the relations and testing for multicollinearity. Stepwise regression models were produced with and without interaction of gender with other dependent variables.

Table 3
Correlations of Selected Independent Variables

	<i>Math Attainment</i>	<i>Computer Experience</i>	<i>Access</i>	<i>Courses</i>	<i>Hours</i>	<i>Programming Experience</i>
<i>Computer experience</i>	.03					
<i>Access</i>	.04	.41***				
<i>Courses</i>	.04	.47***	.08			
<i>Hours</i>	.00	.44***	.39***	.26**		
<i>Programming</i>	.14*	.50***	.26***	.58***	.32***	
<i>Word processing</i>	.03	.55***	.39***	.31***	.37***	.39***

*<.01 **<.001 ***<.0001

Correlational Analysis

Correlations between demographic and attitude variables are reported in Table 2. Note the significant correlations among the attitudes themselves. Also worth mentioning are the significant relations between hands-on variables such as access and programming experience and the attitudes. The importance of these relations was reflected in subsequent regression analysis.

Correlations between demographic variables are reflected in Table 3. Because they are obviously interdependent, correlations are not shown for grade level, age, years of gender-segregated education, and mathematics attainment levels. The analysis confirmed anticipated interrelations among the variables.

Regression Models without Gender Interactions

The model of general attitude was dependent upon three variables (Table 4): hours of use (8.7%), gender (3.5%), and overall computer experience (3.8%). The finding of a higher mean general computer attitude for females than for males was unanticipated ($b = -3.5$, $p < .0001$). Demographic data had indicated seven times as many males as females spent at least seven hours weekly at a computer and twice as many males as females had a minimum of two years of computer experience. The model of attitude toward the computer as a problem solving tool was built from six variables (Table 5). The attitude of females toward the computer as a tool for problem solving was substantially higher than that of the males ($b = -2.4$).

The final gender-uncontrolled model viewed the computer as a tool in the process of written composition. Four variables were significant contributors to the model (Table 6). Gender has been included in the table for comparison with the previous models, although it could not be included in the functional model ($b = -.788$, $p > .05$).

Table 4
Stepwise Regression Model for General Attitude

Variable	<i>R</i> ≤ Cumulative	<i>R</i> ≤ Change	β	<i>F</i>	<i>p</i>
Hours	.087	.087	3.120	41.41	<i>p</i> <.0001
Gender	.122	.035	-3.468	17.03	<i>p</i> <.0001
Computer experience	.160	.038	-1.350	19.54	<i>p</i> <.0001
Full model	.164	.004	—	11.96	<i>p</i> <.0001

df = 1/435

Variables exhibiting *p*>.15 are not reported in this table.

Table 5
Stepwise Regression Model for Problem Solving Attitude

Variable	<i>R</i> ≤ Cumulative	<i>R</i> ≤ Change	β	<i>F</i>	<i>p</i>
Computer experience	.047	.047	1.202	21.81	<i>p</i> <.0001
Gender	.067	.020	-2.393	11.63	<i>p</i> <.001
Hours	.092	.025	1.507	10.68	<i>p</i> <.001
Programming experience	.100	.008	1.972	15.57	<i>p</i> <.0001
Gender-segregated education	.113	.003	-0.816	4.72	<i>p</i> <.03
Math attainment	.116	.003	0.659	3.38	<i>p</i> <.07
Full model	.121	.004	—	11.96	<i>p</i> <.0001

df = 1/444

Variables exhibiting *p*>.15 are not reported in this table.

Attitudes toward computer use without controlling for gender appear to be most strongly affected by hours of computer use and computer experience. Gender had some explanatory power for both general and problem solving attitudes but not for writing attitudes. That computer exposure through coursework was a factor only for writing attitude was an unexpected result. Quite possibly, writing applications were perceived as easier and more conducive to a positive writing attitude than for either of the other attitudes.

Considering the sparsity of computer experience (mean in the range of six months to one year) and the programming emphasis of most computer courses at the time, the exposure may have been sufficient to depress students' attitudes toward problem solving applications. In sharp contrast, note the influence of relevant computer experience upon programming and writing attitudes. It is use, not formal tutelage, that shapes attitudes.

Table 6
Stepwise Regression Model for Writing Attitude

Variable	$R \leq$ Cumulative	$R \leq$ Change	b	F	p
Word processing experience	.065	.065	1.995	31.82	p<.0001
Access	.082	.017	0.617	8.50	p<.004
Computer experience	.091	.009	0.517	4.78	p<.03
Hours	.094	.003	0.766	4.85	p<.03
Gender	.101	.007	-0.788	2.22	p<.14
Full model	.109	.007	—	6.88	p<.0001
df = 1/460					

Variables exhibiting $p > .15$ are not reported in this table.

Regression Models with Control for Gender

Fertsch had suggested that the primary influence of gender was in the context of interactive group effects (Fertsch, 1985). The stepwise regression models with gender interactions reported here underscore Fertsch's assertion with respect to problem solving and writing attitudes. In analyzing general attitude, the only interaction of significance was gender with gender-segregated education (Table 7).

Table 7
Interactive Regression Model for General Attitude

Variable	$R \leq$ Cumulative	$R \leq$ Change	β	F	p
Gender	.122	.035	-3.468	17.03	$p < .0001$
Computer experience	.142	.020	1.470	19.54	$p < .0001$
Gender * gender-segr'd education	.160	.018	-1.350	21.20	$p < .0001$
Gender * access	.166	.006	0.939	3.37	$p < .07$
Gender-segr'd education	.177	.011	1.216	9.07	$p < .003$
Math attainment	.181	.004	0.908	5.85	$p < .02$
Gender * computer exp.	.182	.001	0.776	2.77	$p < .10$
Full model	.191	.009	—	7.68	$p < .0001$

df = 1/435

Variables exhibiting $p > .15$ are not reported in this table.

This combination surfaced again in the model for problem solving attitude (Table 8) along with interactions with computer access and computer experience. Mathematics attainment, gender alone, hours of use, programming experience, and accumulated computer experience also contributed significantly. Negative beta values indicate areas in which the women held the more positive attitude. For example, noting that women reported less than one year of computer experience, they retained the more positive attitude toward the computer as a problem solving tool ($b = -1.182$, $p < .03$). On the other hand, quantity of weekly computer use ($b = 1.282$, $p < .0001$) and cu-

mulative programming experience ($b = 2.66, p < .0001$) contributed more to the positive attitude of males.

Table 8
Interactive Regression Model for Problem Solving Attitude

Variable	R^2 Cumulative	R^2 Change	b	F	p
Computer experience	.047	.047	1.202	21.81	$p < .0001$
Gender * gender-segr'd education	.081	.034	-0.988	15.94	$p < .0001$
Programming experience	.082	.001	2.660	29.53	$p < .0001$
Gender	.100	.018	-2.867	16.77	$p < .0001$
Gender * access	.103	.003	1.662	17.66	$p < .0001$
Hours	.117	.014	1.282	8.14	$p < .0001$
Math attainment	.118	.001	0.562	3.82	$p < .05$
Gender * computer exp.	.138	.020	-1.182	4.77	$p < .03$
Full model	.147	.009	—	4.93	$p < .0001$

df = 1/444

Variables exhibiting $p > .15$ are not reported in this table.

Of fifteen variables in the model for writing attitude, all but four were significant as explanatory agents, including four interaction variables (Table 9). Gender interactions were more prevalent in this model than elsewhere. In considering the entire set of variables, there can be little doubt that increasing amounts of computer usage and regular computer use reinforce positive attitudes toward all uses of the computer.

Across the six models studied, the predominant explanatory forces were cumulative computer experience, hours of weekly use, and gender. Indeed, the hours and experience dimensions were significant contributors to all models. These forces strongly emphasize the importance of regular, hands-on computer experiences in forming positive attitudes. These two items imply undirected experience, as contrasted with coursework, which had little impact on the models.

Table 9
Interactive Regression Model for Writing Attitude

<i>Variable</i>	<i>R² Cumulative</i>	<i>R² Change</i>	<i>b</i>	<i>F</i>	<i>p</i>
<i>Word processing experience</i>	.065	.065	1.995	31.82	p<.0001
<i>Access</i>	.082	.017	0.617	8.50	p<.004
<i>Computer experience</i>	.091	.009	0.517	4.78	p<.03
<i>Hours</i>	.098	.007	0.822	5.45	p<.02
<i>Gender * courses</i>	.100	.002	-0.553	5.29	p<.02
<i>Gender * hours</i>	.104	.004	1.049	6.94	p<.009
<i>Gender * computer exp.</i>	.109	.005	-0.921	8.42	p<.004
<i>Gender * access</i>	.110	.001	0.754	4.75	p<.03
<i>Courses</i>	.112	.002	-0.579	2.43	p<.12
<i>Math attainment</i>	.113	.001	0.660	6.49	p<.01
<i>Gender * math attainment</i>	.114	.001	-1.000	8.98	p<.003
<i>Full model</i>	.132	.018	—	4.52	p<.0001

df = 1/460

Variables exhibiting $p > .15$ are not reported in this table.

The appearance of gender as a significant variable in five of the six models was somewhat unexpected because previous studies had reported no main effect significance. The underlying factors influencing females' more positive attitudes were not, unfortunately, identifiable within the design framework of this study.

Summary

The study leads to several straightforward conclusions. First, in a single-sex educational environment, gender is a significant predictor of computer attitudes. Females in the study held consistently and strongly more positive computer attitudes than did males. Previous attitudinal research, conducted in coeducational situations, reported no such main effect (Fertsch, 1985; Loyd & Gressard, 1984).

Second, the most reliable prediction of computer attitude is based upon knowing the quantity of an individual's past and present computer experiences, both overall and task specific. Respondents with the most positive attitudes were those having the most reported contact with a computer. There can be little doubt that past and present computer experiences are reliable predictors of computer attitudes. The relationship is a positive one: attitude improves as use increases. Throughout this study computer experience, programming experience, and word processing experience were major contributors to the explained variance of the attitudes. These findings confirm earlier studies by Loyd and Gressard (Loyd & Gressard, 1984) and Fertsch (Fertsch, 1985).

Finally, the observation of significant variances for interactive variables supported the "pattern of indirect gender effects upon computer attitudes" found by Fertsch (Fertsch, 1985). The most consistent interactive variables, in terms of significant recurrence and explained variance of attitudes, were those involving access and computer experience. The interaction of gender with gender-segregated education was a strong, significant contributor to both general and problem solving attitudes.

The finding of greatest impact in this study was the identification of main effect significance for gender across the three attitudes. Apparently, in a gender-segregated school setting, gender can be a reliable predictor of computer attitudes. The exact nature of gender's influence, as well as the delineation of factors that permit or enhance gender's effect, need further investigation. Two demographic facts further highlight this issue. First, seven times as many males as females spend substantial amounts of time at a computer each week. Second, twice as many males as females have had more than two years of computer experience.

From a purely rational standpoint, the heavy positive skewing of the distributions for experience variables seems to cloud the importance of gender's predictive quality. The impact of a small group of students exerted an inordinate amount of influence on predictions of general and problem solving attitudes. A practical explanation for this phenomenon could lie in the differing expectations of males and females with respect to the computer. Generally speaking, males expect their programming efforts to be successful and are frustrated by other, less important problems. On the other hand, females exhibit less confidence in their abilities. As a group, they are far more pleased with their efforts when a program works than are males. Success is simply more meaningful, and a positive attitude is more easily fostered.

This study has implications for the planning and implementation of gender-equitable curricula, particularly in single-sex schools. The emergence of gender as a significant predictor of computer attitudes in its own right had not been found in previous studies conducted in coeducational schools. The environment in which this

study was conducted had an effect on the attitudes of the respondents. However, the design of this study did not permit a more precise identification of the relationship. Taken at face value, the gender-segregated environment seems to be more favorable for female students than for males. Thus, for fostering positive computer attitudes, female-only schools have an advantage which they should exploit in the best interest of their students. Whether or not this edge is demonstrable over coeducational environments will require further investigation. This study certainly demonstrated the need for such research. Along these same lines, significant group effects of gender have now been found in two studies and beg further investigation.

References

- Aman, J. R. (1985). A study of gender-related computer attitudes among students in two single-sex high schools. *Masters Abstracts International*, 24/3, 179. University of Houston. (University Microfilms No. MA1327342).
- Anderson, R. E., Welch, W. W., & Harris, L. J. (1984). Inequities in opportunities for computer literacy. *The Computing Teacher*, 11(8), 10-12.
- Benz, C. R., Pfeiffer, I., & Newman, I. (1981). Sex role expectations of classroom teachers, grades 1-12. *American Educational Research Journal*, 18, 289-302.
- Boss, J. A. (1982). Sexism among the micros. *The Computing Teacher*, 9(5), 55-57.
- Cohen, R. F., & Cohen, M. R. (1980). Opening new doors: Taking sex-role stereotyping out of science and mathematics. *School Science and Mathematics*, LXXX, 566-572.
- College Entrance Examination Board. (1985). *National report on college-bound seniors, 1985*. Princeton, NJ: Author.
- Fennema, E. (1980). Sex related differences in mathematics achievement: Where and why? In J. Jacobs (Ed.), *Perspectives on Women and Mathematics*. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education. (ERIC Document Reproduction Service No. ED 166 051).
- Fertsch, D. E. (1985). Gender differences in computer attitudes among middle-school-age students. *Dissertation Abstracts International*, 46/06, Book A. (University Microfilms No. 85-17,700).
- Fisher, G. (1984). The social effects of computers in education. *Electronic Learning*, 3(6), 26-28.
- Kreinberg, N., & Stage, E. K. (1983). EQUALS in computer technology. In J. Zimmerman (Ed.), *The Technological Woman* (pp. 251-259). New York: Praeger Publishers.
- Lockheed, M. E., & Frakt, S. B. (1984). Sex equity: Increasing girls' use of computers. *The Computing Teacher*, 11(8), 16-18.
- Loyd, B. H., & Gressard, C. (1984). The effects of sex, age, and computer experience on computer attitudes. *AEDS Journal*, 18(2), 67-77.
- Maccoby, E. E., & Jacklin, C. N. (1974). *The psychology of sex differences*. Stanford, CA: Stanford University Press.
- Miura, I., & Hess, R. D. (1983, August). *Sex differences in computer access, interest, and usage*. Paper presented at the Annual Convention of the American Psychological Association, Anaheim, CA (ERIC Document Reproduction Service No. ED 238 400).

Online Today, 4 (8): p. 10 (July, 1984).

Rampy, L. M. (1983, June). *We teach the children: Computer literacy as a feminist issue*. Paper presented at the National Women's Studies Conference, Columbus, OH. (ERIC Document Reproduction Service No. ED 240 028).

Schubert, J. G., & Bakke, T. W. (1984). Practical solutions to overcoming inequity in computer use. *The Computing Teacher*, 11(8), 28-30.

Serbin, L. A. (1983). The hidden curriculum: Academic consequences of teacher expectations. In M. Marland (Ed.), *Sex Differentiation and Schooling* (pp. 18-41). London: Heinemann Educational Books.

Shaffer, D. R. (1985). *Developmental psychology: Theory, research, and applications*. Monterey, CA: Brooks/Cole Publishing Company.

Webb, N. M. (1984). Sex differences in interaction and achievement in cooperative small groups. *Journal of Educational Psychology*, 76(1), 33-44.

Whyte, J. (1984). Observing stereotypes and interactions in the school lab and workshop. *Educational Review*, 36(1), 75-86.

Williams, F., Coulombe, J., & Lievrouw, L. (1983). Children's attitudes toward small computers: A preliminary study. *Educational Communications and Technology Journal*, 31(1), 3-7.

About the Author

James R. Aman is currently at Wilmington College in Ohio. He earned his B.A. at Texas Christian University, his M.Ed. at the University of Houston, and his Ph.D. at the University of North Texas.

His recent publications include;

Aman, J. (1990). Computer science in correctional education. *SIGCSE Bulletin*, 22 (1).

Aman, J. (1988). *Cognitive level demands of test items in state-approved computer science textbooks*. Doctoral dissertation, University of North Texas.

Recent noteworthy activities include the paper, "Spousal Communication in Iranian-American Couples," presented at the Sixteenth Conference of SIETAR, in Kilkenny, Ireland, and his recognition for teaching excellence in 1990 by the Greater Cincinnati Consortium of Colleges and Universities.

His research interests include: gender equity in computer use; gender-blind programming, specifically of computer-assisted instruction; and intercultural and transcultural communication.

Female Students' Underachievement in Computer Science and Mathematics: Reasons and Recommendations

Lesley S. Klein

Pace University, Pleasantville, NY

Research has shown that, overall, female students have a higher verbal self-concept than male students, yet lower self-concepts in their abilities in mathematics and computer science than males. The following paper explores how self-concept and other factors, including traditional attitudes toward mathematics, teachers and parents, role models, and software design, influence girls' attitudes toward the study of computer science.

Introduction

My intrigue in boys' greater interest in computer science than girls' was born from four years of teaching computer science in a gifted education program for grades 5 through 11. Students are recommended for the program by teachers and guidance counselors. The prerequisite for acceptance is to pass a screening given by specialists in gifted education who look for interest and aptitude in the subject area. In four years, the gender pattern has remained consistent. On the fifth-grade level, the gifted class is approximately one-half girls and one-half boys. After the fifth grade, only male students have been identified as gifted in computer science.

When I visit computer labs in local schools and observe the clientele during "open lab" time, I frequently see an even distribution of boys and girls in elementary school, but there is a difference in their choice of software. The boys are often "shooting" gunfire at correct answers, winding a little man through a maze, or enthusiastically hunting for gold, criminals, and other treasures, hoping to find their name at the top of the electronic score card. The girls are correctly answering math problems that reward them with a few bars of electronic music and a colorful picture, writing stories or newspaper articles on a word processor, creating designs, and engaging in adventure games merely to compete against themselves without as much concern about their score card status relative to the other players.

In middle school, the computer time is always consumed by the boys who rush in, desperate to continue where they left off the day before in *Oregon Trail*, *Karateka*, or *Carmen San Diego*. An occasional girl wanders in, but she would need to be uncharacteristically aggressive to gain access to these monopolized computers.

The pattern of voluntary computer usage by girls improves in high school. While male attendance predominates, females have a smaller but significant showing. Girl programmers can be found, but boys are more often enrolled in programming courses that require them to work in the lab, and they are more inclined to program for enjoyment and experimentation than for the purpose of handing an assignment in on

time, which is often the reason that female students program during open lab time. Students of both genders frequently use word processors, but more girls use the sophisticated Macintosh desktop publishing facilities than do boys, who seem content using Appleworks on the Apple II series. I have never witnessed females participating in robotics projects, although in the fifth grade, girls were as interested as boys in Lego Logo (an introduction to robotics).

I have seen a wide variety of capabilities in the faculty who teach computer usage and programming. In lower grades, this is often the responsibility of a teacher aide or media center administrator who has had in-service training. Occasionally students have a classroom teacher who is interested in computers as a hobby or has taken some computer education courses. Some more adventurous teachers have incorporated Logo or Lego Logo programming into the curriculum, but there is no apparent formal plan or carry-over from one grade level to the next.

Not until the seventh- and eighth-grade level does the study of computers, logic, or BASIC programming emerge. Finally, Pascal and C programming, as well as an introduction to data processing, are offered in many secondary schools. Some teachers assigned to teach secondary computer education are knowledgeable and either hold masters degrees in computer science, or have taken graduate courses, staying abreast of the most recent theory or technology. Others are math or industrial arts teachers who have received minimal training and support in their efforts to teach this relatively new and evolving subject.

The following section gives a description of significant studies of elementary, secondary, and college students' attitudes toward computers and is followed by suggestions for improvements in computer education.

Review of Literature

Self-Confidence in Mathematics and Computer Science

Why do girls begin primary school with equal self-concepts in math and at least equal achievement, only to avoid math computer classes in secondary school and college and eventually choose careers that do not involve mathematics? In the following section I will cite sex differences in mathematical achievement in schools (middle through college), explore possible reasons for the differences, and finally cite studies that show the relationship between students' attitudes toward mathematics and those toward computer science.

A study was performed on male and female AP math students at Hunter College High School (Strauss, 1988). The mean score on the AP calculus exam was 0.55 points higher for the boys than for the girls (statistically significant). On average, males scored 55 points higher on the math portion of the SATs than females did. On the math achievement tests, boys scored 26 points higher than girls on Level I, and 13 points higher on Level II. Yet, the math G.P.A. for both sexes were virtually the same. The overall G.P.A. for girls was 1.7 points higher than for boys. Why is there such an inconsistency between standardized test scores and school averages? Are the tests somehow biased? Do teachers expect more from male students than female students

in math? Why is girls' school achievement higher than their standardized test scores indicate? Is it because they are more eager to please their teachers and more diligent in handing in homework assignments? Do we encourage autonomous and creative thinking (important in higher level cognitive skills) less for our female high school students than for the males?

The results of one international study reveals that sex differences in math achievement tend to be caused by cultural rather than genetic differences (Ethington, 1988). The reason for this conclusion is that while girls in most nations scored lower than the boys of their own country, they had higher scores than boys of other countries (who in turn scored higher than the girls in their own country and so forth). While males excelled in math as compared to females overall, the male achievement level varied greatly from one country to another. The exceptions were among native Hawaiians, Filipino-Americans, and Japanese-Americans whose girls scored higher than their male counterparts.

Male-dominated mathematical areas included measurement and proportion problems and, generally, questions that involved spatial relations. Males scored higher overall in problem solving, but females excelled in computational skills, abstract deductive reasoning, and symbolic relationships such as sets.

In the latest Second International Mathematics Study (SIMS) a math test was administered to students in eight countries: Japanese seventh graders, and eighth graders in Belgium, British Columbia, France, Ontario, The United States, New Zealand, and Thailand. Test questions were drawn from the curricula of each country, giving a fair balance of test questions. The categories included: fractions, ratio/proportion/percent, algebra, geometry, and measurement. This time, there were no statistically significant differences overall between genders, although the greatest areas of difference were in fractions, in which girls excelled, and geometry, in which boys excelled. Why is there a discrepancy between this study and the previous studies? Did cultural differences improve, or more likely, was this test (SIMS) better designed? The author of this recent study postulates that gender differences usually found in math performance are due to a blend of curricula, teaching methods, and culture.

What happens to these girls, who entered primary school with a similar self-concept to boys, by the time they reach college? A study was conducted on college freshmen to compare their attitudes toward math courses and future careers (Lips, 1988). Men put higher value on math than women did. According to the questionnaire results, women often gave "lack of interest" as their reason for not taking math courses. Also cited was women's expected lack of success in math courses.

In a study of students in the northeastern region of the United States, Kwan hypothesizes that the reasons behind mathematics underachievement will be a clue to computer underachievement (Kwan, 1985). The results of Kwan's study concluded that gender differences in interest in computers followed the same path as that of mathematics. Reasons include girls' low self-expectations, lower test scores, poorer spatial ability, and greater math/computer anxiety. In lower grades (pre-high school), students perceive both math and computer professions as male dominated and having

less relevance to a woman's future career. Females are less motivated by memorization tasks than by creative tasks; this fact may help educators to improve their style of computer instruction. Programming, as a problem solving tool, offers many opportunities for creativity in teaching. Kwan found a more positive attitude toward computer science in his survey of female high school students enrolled in accelerated mathematics classes. They tended to reject the notion that computers are a male domain, but felt the media too often portrayed it as such. They also felt that computer knowledge would be useful in their future careers. Thus, according to Kwan, girls who experienced success in mathematics were more positive about the study of computers than were the general population of female students.

Guinan and Stephens conducted a study that suggests that gender was actually an independent factor in computer science achievement, while mathematics background and GPA were the primary factors (Guinan & Stephens, 1988). Their study compared male and female secondary students' success in two introductory computer courses. The first included flowcharting, coding, and FORTRAN, and the second involved basic concepts, history, and principals of computers. Girls preferred the latter course, while boys more frequently chose the former. If math background is a primary factor and the general population of female students suffers from more math anxiety and less experience, then gender does become a secondary factor.

Software Design

A study by Wilder suggests that masculine software design, beginning with video arcade games, is preventing girls from developing a sense of "ownership" toward computers (Wilder, 1985). She observes that boys dominate video games while girls merely act as spectators. Other voluntary computer-related activities demonstrate the same pattern, including computer clubs and computer camps. Although the responses to this survey of elementary school children indicated that boys and girls did not have very strong attitudes regarding gender-related factors and computer interest, the children did perceive computers to be appropriate for boys, the boys indicating stronger feelings than the girls.

Perhaps the most significant aspect of Wilder's findings is that the interest in computers of both male and female students declines rapidly beginning in the sixth grade. A possible explanation for this is that computer instruction changes from "fun" applications to computer theory and more serious applications.

Hawkins addresses another software problem (Hawkins, 1985). An elementary school class in which a teacher was instructed to be sensitive to the needs of unmotivated girls was given the opportunity to use the computer with three software packages. One measured physical data such as temperature, light, and sound. The second was a simulation game for geometry and navigation. The third was a series of games to introduce Logo programming. The second and third packages required collaboration among students in small groups, while the first was designed for individual use. Teachers reported that girls preferred and participated voluntarily in

the use of the two packages which were socially oriented. Previous to this study, the teacher had tried to introduce Logo programming without the collaborative software. Girls were not as motivated as boys, even with a prize incentive for the best programmer, most improved, most enthusiastic, etc. Only male students won the prizes. After the study, however, a few girls earned these awards. Successful female programmers were good students in most academic subjects, yet this was not true of the successful male programmers.

Positive/Negative Feedback

Another factor Hawkins observed during her study was the importance of the quality of feedback students received from their teacher. Female students lost confidence more quickly than males if there was little or no feedback, although it was not as important during social tasks as individual ones. As in the case of mathematics, a high degree of competition in the classroom setting was discouraging for females. Finally, Hawkins observed that when schools acquire hardware and software, they do not receive enough training and support for its use, confirming the findings of another study by Fetler (Fetler, 1985).

A revealing study was made of teacher responses to fourth-grade students (Lockheed, et al., 1984). Responses to students were categorized as positive feedback, recognition, moving on, praise, explanation/help, redirection, and negative feedback. During math lessons, boys did not receive negative feedback in any activity. Responses to boys included recognition, positive feedback, explanation/help, redirection, and in one case, moving on (in order of most to least frequent). On the other hand, teacher response to girls in the same class were moving on, negative feedback, recognition, one case of ignoring, and one case of explanation/help. Responses during reading class were completely different and less sex biased.

Parental attitudes may influence a student's self-concept. A study was conducted to compare the math achievement of students whose parents had no college degree with students whose parents had at least a bachelor's degree (Jayaratne, 1987). The subjects were fifth- through twelfth-grade students and their parents. All were of middle/working class socioeconomic groups. Subjects completed a questionnaire on self-perception of their math ability and their expectations for taking math classes. They were asked about their parents' feelings towards math, including their ability, enjoyment, difficulty, and past attitudes toward high school math. Parents were questioned about their child's ability and effort in math.

Comparisons were made not only between college and non-college educated families, but between same sex parent and child and opposite sex parent and child within the original two subgroups. Researchers expected to find positive correlations between all higher educated groups, but the only statistically significant correlation was between mothers with higher education who had a positive attitude toward math and their daughters. The closest correlation centered on mothers' positive memories of high school math, not around their present self-concept. The author of the study

suggests two reasons for this. First, the mothers' memories are invoked by observing daughters doing homework, resulting in either sympathy or enthusiasm, but nevertheless support. Second, math may not be part of the mothers' present career demands.

The reason that fathers and sons do not have the same relationship is perhaps because fathers are not as willing to admit to any weaknesses in math and sons may not be willing to admit that they are struggling in math. Parents may not wish to share negative experiences in math with their sons, to avoid being a negative influence. The study did not completely support the above assumption, but children of higher educated parents overall were more perceptive of their parents' attitudes toward math. Finally, how mothers' attitudes toward math influence their daughters' was independent of the mothers' expectations of their daughters' accomplishments in math.

Gender differences in perceived encouragement from same-sex peers were statistically significant, with men rating higher. The differences in encouragement from opposite sex peers and parents were not statistically significant. When the subjects were questioned on expected enjoyment of college courses, women responded significantly more positively to social sciences and English while men responded more positively to computer science and mathematics. Men expected to perform well in math courses, while women expected to do poorly. The results were the same when subjects were asked how they would succeed in relation to others in the class.

While women generally did not agree that mathematics was a "male domain," they reported more math anxiety; males had more confidence in their ability to learn math. When asked why they do not perform well in math, women attributed low ability and discouragement by others as the main reasons. The men perceived women as not as able to handle computers. The most discouraging result of this study is that men stated a significantly greater intention to take math courses in the future than women did.

In the same study, college students were asked many questions about career choice. Men rated the opportunity to earn a high salary much higher than women, who focused on working with people, combining career and family, and performing well on the job. Men agreed much more strongly than women with the following statements: It is difficult for a woman to combine a scientific career and family life; a woman chemist or physicist who takes time off from her career to have children will never catch up again; a woman planning a career as a mathematician or scientist should plan not to have children; a woman dedicated to a career in science or mathematics would not be able to devote much time to her family. Unfortunately, only 11 out of the 251 female respondents of this study planned a career in either mathematics, physics, chemistry, computer science, or statistics.

There is evidence that negative attitudes of female high school students toward computers does not improve in college or in the workplace (Gattiker; Miura, 1986). Many studies replicate the finding that males perceive computer knowledge as more valuable to them in future careers than do females. Females more frequently use computers as a tool for electronic banking and mail, but males are more confident in

their programming skills and feelings of "ownership" of computer skills (Popovich, et al., 1987).

Miura found that experience in a high school computer course and current enrollment in a college computer course were the two most important gender-independent factors in college computer course enrollment, in her study to understand self-efficacy in gender differences in selecting college computer courses (Miura, 1986). Yet, without voluntarily enrolling, female students cannot gain the experience that inspires the self-confidence that leads to pursuing further computer courses.

Suggestions

A starting point in rectifying the problem is to clarify and formalize computer science curricula on the precollege level. Fetter states that both male and female students underachieve in computer skills because of the novelty of computer studies, lack of qualified teaching staff, and confusion over what should be taught (Fetter, 1985). I have observed improvement in teachers' comfort and proficiency in teaching computer science over the past four years, but the "remain one step ahead of the students" method still prevails in classrooms that at least attempt to update their information. Many elementary and middle school classes continue to teach the same outdated and poorly designed BASIC programs year in and year out.

Marsh suggests single sex (all female) accelerated or remedial math groups (Marsh, et al., 1988). She also recommends identifying gifted female math students and supporting them with extra encouragement and opportunity to meliorate their talent, such as computer classes and gifted math classes.

The following are suggestions for the improvement of computer education on the secondary and pre-secondary levels:

1. Introduction to computer courses should be required in secondary schools. Since previous experience with computers and computer courses leads to a more positive attitude toward computer course electives, more female students may be ready to enter college as computer science majors if they have previous experience in high school.
2. Incorporate computer usage into school curricula during transition periods (i.e., entering middle school and entering high school). During these years, female students demonstrate more insecurity and lack of self-confidence in math and science, which sets them behind male students in the remaining school years.
3. Develop a more consistent relationship between classroom teachers and educational software designers, stressing the need for less competitive software.
4. Incorporate group projects in the classroom as often as individual assignments. Projects should relate to issues of social relevancy because of female secondary school students' greater interest in social issues (i.e., design a program in Pascal or C that conducts a market research survey and tabulates and/or evaluates responses).

5. Incorporate greater use of telecommunications through which computer literacy is learned in conjunction with other stimulating educational projects.
6. Formalize curricula to develop student interest in technology on all grade levels that carry over from one year to the next, rather than the present ad hoc references to technological advancements.
7. Provide a secondary level computer science class with problem solving as its purpose, and program design and logic as the tools used for sharpening problem solving skills. The learning atmosphere should be non-competitive; teachers may find that grouping according to gender would increase female students' participation.
8. Invite women in industry to cooperate in projects with local schools, providing role models for female students.

Conclusion

There are a wealth of published studies that establish the fact that female students are, overall, less interested in computer science than their male counterparts, for reasons of low self-image, competition, identification of computers with math and science, male orientation of software, and inadequate computer education curricula. Perhaps computers are perceived by students as a male domain because that is how they are presented in software, in the media and in the classroom.

A three-step process can aid in the remedy of the problem: 1) the publication of a formal, secondary level computer science curriculum for grades 7-12; 2) distribution of said curriculum and support for its implementation; 3) teacher training for improvement of computer skills and lesson presentation, specifically addressing the motivation of female students. On a personal note, I took my first computer course as a college elective in order to overcome my fear of technology and because I felt it would be beneficial to any career I might pursue. Success in my first programming class (taught by a woman with superior mathematics as well as communication skills) led me to a second programming elective, taught by another woman. At the end of the semester, that professor encouraged me to consider a career and enroll in a graduate program in computer science and information systems. All of the positive elements were in my favor: encouraging feedback, female role models, confidence in my math skills, and the completion of two computer courses. I hope that we can impart the same support extended to me by that professor to our current and future female computer students.

References

- Ethington, C. A. (1988, April). *Gender differences in mathematics: An international perspective*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, Louisiana.
- Fetler, M. (1985). Sex differences on the California statewide assessment of computer literacy. *Sex Roles, 13*, 181-91.
- Gattiker, U. E. *An assessment of computer attitudes and their effect on career success*. Lethbridge University, Alberta, Canada.
- Guinan, T. and Stephens, L. (1988, Fall). Factors affecting the achievement of high school students in beginning computer science courses, *Journal of Computers in Mathematics and Science Teaching, 8*, 61-4.
- Hawkins, J. (1985). Computers and girls: Rethinking the issues. *Sex Roles, 13*, 165-180.
- Jayarathne, T. (1987, April). *The impact of mothers' math experiences on their daughters' attitudes toward math*. Paper presented at the biennial meeting of the Society for Research in Child Development, Baltimore, Maryland.
- Johnson, L. (1987, May-June). Children's visions of the future, *The Futurist, 21*, 36-40.
- Kwan, S. K. (1985, September). Gender differences and computing: Students' assessment of societal influences. *Education and Computing, 1*, 187-94.
- Kfir, et al. (1988, Summer). Achievements and aspirations among boys and girls in high school. *American Educational Research Journal, 25*, 213-36.
- Lips, H. M. (1988). *The role of gender, self, and task perceptions in mathematics and science participation among college students*. Paper presented at the Social Sciences and Humanities Research Council of Canada, Ottawa, Ontario.
- Lockheed, M., et al. (1984, March). *A study of sex equity in classroom interaction: Vol. 2*. National Institute of Education, Washington, D.C.
- Lockheed, M. E. (1985). Women, girls, and computers: A first look at the evidence. *Sex Roles, 13*, 115-122.
- Marsh, et al. (1988, Summer). The transition from single-sex to coeducational high school, *American Educational Research Journal, 25*, 237-69.
- Miura, I. T. (1986, April). *Computer self-efficacy: A factor in understanding gender differences in computer course enrollment*. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, California.
- Popovich, P. M., et al. (1987, Spring). The development of the attitudes toward computer usage scale, *Educational and Psychological Measurement, 47*, 261-69.
- Skolnick, J., et al. (1982). *How to encourage girls in math and science*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.
- Strauss, S. M. (1988, October). Girls in the mathematics classroom: What's happening with our best and brightest? *Math Teacher, 81*, 533-7.
- Wilder, G. (1985). Gender and computers: Two surveys of computer related attitudes. *Sex Roles, 13*, 215-228.

About the Author

Lesley S. Klein holds an M.S. in Computer Science, and is currently at Pace University. She was recently the Panel Coordinator for the ACM Pre-College Committee Panel on the "College Preparatory Course in Computer Science for High School."

Implications of the Computer Culture for Women of Color

Carol Edwards

Southern Coalition for Educational Equity, Atlanta, Georgia

A personal reflection:

*I asked ten friends of mine, all girls and women of color, to paint a picture for me of the person who came to mind when I said the words "computer scientist." Nine out of ten said **he** was **white** and **wore a tie**. Unfortunately, this is both the image and the reality of computer science professionals—mostly male, mostly white, mostly from middle class or aspiring middle class backgrounds.*

*Where are women of color in computer science? In image, nowhere. Well, not completely... there is one Asian woman among the professionals, ...a few African-American and Hispanic women **wordprocessing** in the **back**. One in the front, and a few in the back—that image, although not quite accurate, does reflect the implications of computer culture as they exist today for women of color. Yet, as Sam Cooke sang so beautifully, "...but I know a change is gonna come."*

—Carol Edwards

The World of Education

Girls of color, by and large, share the same circumstances of gender discrimination as white girls, with the addition that racism compounds sexism. Discrimination against women of color often leaves them in poverty, adding class bias to their lives and those of their children. These double and triple doses of discrimination work together to reinforce limitations on the early opportunities for minority girls to advance down the science pipeline.

The pipeline through which many computer science careers, as well as those in mathematics, engineering, and science, are achieved is long and inflexible. The typical path includes:

- facility, both teacher and student perceived, with basic computational skills by grade four
- algebra before grade ten
- academic track in high school
- mathematics and/or science electives
- good grades in math and science
- above average SAT or ACT scores
- extra curricular hours devoted to science or math endeavors
- a computer science (mathematics, engineering, or science) major in a four-year college

In addition, many future computer scientists share social reinforcement for the science pipeline including:

- adult praise in reaction to success with arithmetic and mathematics
- hobbies, extra curricular and/or leisure time activities that are related to science
- a mother with a college degree
- close parental monitoring of studies
- positive reinforcement, or at least the absence of serious negative reinforcement from peers
- interaction with role models and mentors

Those in the science pipeline have been found to be confident in their math and science abilities. (Gardner, et al., 1989).

Schooling and social experiences for girls (and boys) of color are often very different from those who follow the science pipeline. First, inferior elementary schooling—low teacher expectations, limited access to instructional materials and supplies, inexperienced teachers, teachers with little knowledge of, or respect for, the children's culture and environment—relegates girls of color disproportionately to low tracks in mathematics by the upper elementary grades. Once in a low track, there is very little chance of moving to a higher track (Oaks, 1985).

The lack of cultural synchronization between children of color and white teachers results in poor student-teacher communications and limits students' learning opportunities (Irvine, 1990). A teacher who ignores, misinterprets, or devalues the children's beliefs, customs, and values, or fails to understand their natural language (Orr, 1987), often provides them with little positive teaching attention and limits their motivation and achievement. Although it is often unwittingly done, the children find the divergence between their own and their teachers' behavior and beliefs confusing and hurtful. They turn off from learning. Also, some experts believe that cognition is culturally influenced and that minority and white children have different cognitive styles (Hale-Benson, 1986).

There is some evidence that locus of control, an important factor in learning, is associated with socio-economic status (Ornstein and Levine, 1989). Internal locus of control, a characteristic of scholastic achievement, is greater among high socioeconomic status (SES) students than low SES students.

Girls of color lack science-related opportunities in or near their communities; are less likely than average to have mothers with college degrees; are less likely to have hobbies, extra curricular and/or leisure time activities that relate to science; lack parental awareness; and have income limitations. Home conditions that are not conducive to close monitoring of scholastic performance and responsibility for the care of younger siblings are more apt to affect girls of color.

The recent work of several scholars suggests that many girls and boys of color measure their self esteem in non-academic ways, and that the importance of academic competence to their overall view of themselves as worthwhile and accomplished

people is slight. For girls who have experienced limited positive reinforcement and success in school, and who are not exposed to academically successful role models, choosing non-academic measures of self esteem should not be surprising.

Moreover, several complex reasons, including the protest of ethnic discrimination, have precipitated the phenomenon of anti-intellectualism in the lowest income, isolated, minority communities. The peer pressure this anti-intellectualism generates helps to dissuade minority girls from engaging in and valuing behaviors perceived as scholarly.

Role models and mentors in computer science are also sparse for girls and young women of color. Ideally, role models should be close in age and similar in background to the girls for which they are models. Often, in low income minority neighborhoods there are no adolescent girls with high math and science achievement to serve as role models for younger girls and no young women of color who are computer scientists to serve as role models for high school girls.

Geometry, the Gate Keeper

Pre- and early-adolescent conditions for many girls of color, both in and out of school, conspire to prevent them from participating equitably in the most decisive step along the science pipeline: high school mathematics. Algebra and geometry courses are not only important in the computer science pipeline, but for students of color they are also key to the broadest options for postsecondary study. More specifically, a recent study conducted for the College Board reported that girls and boys of color who take high school geometry enroll in college at almost the same rates as whites. This finding reinforced results of an earlier study that reported that completion of an algebra course in ninth grade was the best predictor of college attendance among African-American students. Tracking, as well as other conditions, including poor counseling, meager course offerings (such as the lack of pre-algebra curriculum in predominantly minority schools), the lack of expert math teachers, few informal opportunities to engage in practical or fun mathematics activities outside of school, and low expectations for college matriculation by parents, conspire to prevent girls of color from enrolling in entry-level algebra and geometry.

Intervention Programs are Effective

Yet progress has been made. There is a growing number of academic and community intervention programs targeted toward youth of color and a few specifically toward girls of color. Well-designed intervention programs pay off. Programs developed by regional minority engineering academies, math and science networks, and organizations like the American Association for the Advancement of Science, Jack and Jill Clubs of America, and the National Urban League provide structured and nurturing experiences in technology, math, and science tailored to students of color.

The goal of these programs is to add more women and men of color to science and technology professions. Having goals that focus on increasing college majors or jobs

in technology seems more effective than goals that simply aim to increase technological literacy or feelings of comfort with technology. The strategies used in these intervention programs target children of color at an early age, try to interest them in math and science, and continue to work with those who show talent through their high school years. The kinds of activities these programs provide generally begin with hands-on, fun, or practical science and math and proceed to more abstract, theoretical learning experiences. Also, they often provide general academic support, such as SAT preparation and homework tutoring. After-school, summer, and weekend programs for the youngsters are offered, as well as staff development programs for public school teachers. Usually parents are required to be an integral part of the program. Mentors, role models, and visits to college campuses supplement the academic activities. In the opinion of many equity advocates, these comprehensive intervention programs, in large measure, have been responsible for a recent increase in African-American, Hispanic, and Native American computer science and science baccalaureates.

From the mid-1980s, computers have become glamorous. With the rising availability of microcomputers and the hype of the Information Age, computer careers have become careers of choice. Suddenly many young people, including many girls of color, have become interested in working with computers. This interest helped to spur an increase in enrollment in computer-related post-secondary studies.

The modest increase in African-American, Latino, and Native American computer science majors in four-year colleges was accompanied by a larger increase in computer-related course enrollment at the more affordable proprietary schools. Among the legitimate proprietary schools everything from keyboarding to applications to programming to computer repair was offered and varied in quality from very poor to excellent. Proprietary schools became a primary conduit for women of color into the world of computers, in part because their admission requirements took a more flexible view of the science pipeline, and partly because their instructors were viewed as more responsive and less elitist. As profit-making institutions, they made potential students—their customers—feel welcome. They often offered both financial assistance and help wading through financial aid paper work. Also, proprietary schools were organized to accommodate the schedules of the more mature, working student, a category into which a large percent of students of color fit. Community colleges were also attractive to women of color for similar reasons. Moreover, community colleges often provided the only learning institution within commuting distance for single, working mothers in small towns or rural areas.

A look at fields of study among people of color reveals that small (but in a few instances equitable) numbers of women of color are represented in computer-related areas. In postsecondary institutions slightly over half (54%) of the African-American and nearly half (46%) of Native American computer science majors and those studying computer programming are women. It must be emphasized however, that the total number of African-Americans and Native Americans majoring in computer-related fields in four year colleges is very small. For example, only 4.3% of the

bachelors degrees awarded to African-Americans in 1988-89 were awarded in computer science. In that same year, only 2.3% of the bachelors degrees awarded to Native Americans were awarded in computer science. Among Hispanics (43%) and Asians (39%), underrepresentation of women is the rule.

Table 1
Computer and Information Science Majors, Bachelors Degree

	<i>Men</i>	<i>Women</i>	<i>Total</i>
<i>White</i>	19,793	9,388	29,181
<i>Black</i>	1,284	1,536	2,820
<i>Hispanic</i>	594	444	1,038
<i>Asian</i>	1,490	965	2,455
<i>Native Amer.</i>	61	51	112
<i>Non Resident</i>	1,775	802	2,577
<i>All*</i>	25,865	13,724	39,589

Masters Degree

	<i>Men</i>	<i>Women</i>	<i>Total</i>
<i>White</i>	3,229	1,488	4,717
<i>Black</i>	126	81	207
<i>Hispanic</i>	91	32	123
<i>Asian</i>	522	257	779
<i>Native Amer.</i>	19	3	22
<i>Non Resident</i>	1,575	492	2,067
<i>All</i>	5,985	2,496	8,481

Doctorate Degree

	<i>Men</i>	<i>Women</i>	<i>Total</i>
<i>White</i>	169	40	209
<i>Black</i>	1	1	2
<i>Hispanic</i>	5	1	6
<i>Asian</i>	15	4	19
<i>Native Amer.</i>	1	0	1
<i>Non Resident</i>	115	5	120
<i>All</i>	322	52	374

* Totals include degree recipients whose race is undetermined.
1986 -1987 data from the National Center For Educational Statistics

The World of Work

Armed with a certificate from a proprietary institution, an associate degree, or bachelor's degree, a woman of color attempts to enter the computer work world. What is open to her?

Between 1983 and 1988 there has been an increase of 116% in African-American and 83% in Hispanic workers in the field labeled "Mathematical and Computer Scientist" according to the U.S. Department of Labor, Bureau of Labor Statistics. Although these increases may appear to be large, both groups remain underrepresented in this occupational category. African-Americans made up 7% and Hispanics 3% of the total of this occupational title in 1988.

Indeed, the higher paying and more prestigious computer science occupations and those requiring postgraduate degrees are still virtually closed to women of color. Among "Computer Systems Analysts and Scientists" in 1989, for example, there were 13,000* African-American women and 4,000* Hispanic women compared to 338,000* white men and about half that number of white women (see Table 2). Positions such as senior manager of computer hardware and software companies, manager of major data processing installations, and senior-level computer programmer for scientific and military systems have very small numbers of women of color. Although women have made some progress in recent years, they often hold technical support positions that are outside of the main decision-making line. African-American women are making gains as computer programmers, but are still underrepresented as are African-American men. Among college and university computer science teachers in 1989, there were, combined, fewer than 1,000* Hispanic men and women, and fewer than 1,000* African-American women, compared to 11,000 white males.

The overwhelming majority of women of color who work in the computer-related fields are office support staff working with word processors and workers in manufacturing plants, for example, textile plants, operating computer-controlled machines. Among computer-related jobs, these positions command low salaries and have little influence in shaping the computer culture.

The World of Leisure

Women and girls of color are underrepresented in every aspect of computer games. They are not the developers of computer games, nor are they represented in the graphics of games themselves. There are no data available on the number of women of color who purchase computers for home use. However, female-headed families, in which women of color can be assumed to make purchasing decisions, have incomes below that of the average household that owns a personal computer. It is interesting to note, however, that among African-American families that own home computers, there is evidence that they are as likely to buy them for their girls as they are for their boys (Edwards and Irvine, 1985). Computer networks that offer services such as home

* Rounded to the nearest thousand

Table 2
Selected Computer-Related Occupations (Numbers in Thousands)

	Computer Systems Analysts & Scientists		
	<i>Men</i>	<i>Women</i>	<i>Total</i>
<i>White</i>	338	162	501
<i>Black</i>	19	13	32
<i>Hispanic</i>	13	4	17
<i>All*</i>	383	184	566

	Computer Programmers		
	<i>Men</i>	<i>Women</i>	<i>Total</i>
<i>White</i>	327	168	495
<i>Black</i>	13	18	31
<i>Hispanic</i>	11	7	18
<i>All*</i>	364	198	561

	Supervisors of Computer Equipment Operators		
	<i>Men</i>	<i>Women</i>	<i>Total</i>
<i>White</i>	18	15	33
<i>Black</i>	2	1	3
<i>Hispanic</i>	0	2	3
<i>All*</i>	20	16	37

	Computer Operators		
	<i>Men</i>	<i>Women</i>	<i>Total</i>
<i>White</i>	251	464	715
<i>Black</i>	46	78	124
<i>Hispanic</i>	28	24	52
<i>All*</i>	312	559	870

	Data-Entry Keyers		
	<i>Men</i>	<i>Women</i>	<i>Total</i>
<i>White</i>	40	273	313
<i>Black</i>	9	75	84
<i>Hispanic</i>	7	28	35
<i>All*</i>	51	364	414

	Data Processing Equip. Repairers		
	<i>Men</i>	<i>Women</i>	<i>Total</i>
<i>White</i>	116	11	126
<i>Black</i>	16	2	18
<i>Hispanic</i>	6	1	7
<i>All*</i>	139	13	152

* Totals may include workers whose race was undetermined.

banking and shopping generally provide them in affluent, predominantly white communities first. Thus, even in households where women of color have access to computers with modems, they are less apt to have a full range of computer services available to them unless they live in affluent, white communities.

Women of Color and the Computer Culture

Most women of color are passive recipients in the computer culture. Their most common experience with computers is to be told, "it's the computer's fault" when victimized by bureaucratic delays and inflexibility. Participation in shaping the computer culture is out of their hands.

There is a growing number of women of color who are advocating change, however. In particular, they want girls and boys of color to have greater access to microcomputers at school, to become computer literate at an early age, and to improve basic skills. They are also working with churches and community centers to improve out-of-school access to computers for tutoring, dropout prevention, G.E.D., and job skills training programs. Their emphasis is not on computer science or computer programming *per se*. Rather, it is on computers as a vehicle both to academic achievement in all subject areas and to better jobs.

Of women of color working in the computer industry, the largest percent work in non-professional positions. However, the number of women of color in computer programming, data processing, and systems analysis is slowly increasing. There remains virtually no representation by women of color at decision-making levels in computer-related fields. Both their small overall number and their absence from influential positions in the industry mean that women of color will not have a role in determining the nature of computer culture in the foreseeable future.

Recommendations

The current picture is disappointing but not hopeless. Although complex and difficult to implement, changes can be made that will permit women of color the opportunity to participate fully and equitably in every aspect of the computer culture. Many of the steps that must be taken to attain this goal are known. The following recommended changes in educational and workplace opportunities for women and girls of color will begin to afford them more significant inclusion:

Early Learning, Elementary, and Secondary Education

- More publicity and education in communities of people of color about the nature and importance of non-gender-biased parenting
- Accessibility to high-quality child care facilities where teachers receive periodic training in gender equity within a culturally sensitive context
- Elimination of ability tracking
- More study of successful teachers of girls and boys of color, and incorporation of their practices into teacher preparation and staff development programs

- Periodic equity training for all teachers
- Inclusion of equity as a measure in evaluating teachers
- Restructuring the educational workplace so that low income, minority schools become highly desirable places to teach; this change could be accomplished through incentives such as bonus pay, greater professionalism, and higher prestige that would encourage the most talented teachers and principals to go to these schools voluntarily.
- Interweaving of the children's culture and environment into instructional materials and practices, and attending to the roles of women and girls; this change would require the knowledge and value of the children's culture and of women's roles in that culture.
- Inclusion of cultural politics in instruction
- Provision of more and earlier opportunities to use microcomputers and other technology as productivity tools
- Development of computer programming courses that appeal to girls of color as demonstrated by successful outcomes; after an adequate pool of teachers has been trained to teach these courses effectively, beginning and intermediate computer programming would be mandated in the middle grades for all girls of color.
- Requirement that all students take algebra and geometry coupled with the revision of the curriculum and instruction to make the courses effective for all
- Provision of incentives (time off during work hours, criteria for promotion, etc.) by businesses for young women computer scientists and programmers of color to volunteer with economically disadvantaged girls of color, particularly through their early and mid-adolescent years
- Provision of better and more frequent counseling to girls of color and their families; provision of periodic equity training to all counselors
- Establishment of measures of instructional success that include equitable numbers of girls and boys in all math and science classes, including electives
- Extra-curricular math and science activities that appeal to girls of color
- Greater funding for practices that have already been proven to work with children of color, such as Saturday academies, tutors, special summer programs, and community-based centers

Post Secondary

- Elimination of the SAT and other biased measures as criteria for college admission; involvement of women of color trained in equity in the development or selection of alternative assessment measures
- Provision of more financial aid, particularly in the form of grants; provision of aid that is not tied to SAT or other academic determinants
- Creation of adequately funded student service departments that respond to the social needs of students

- Equity and cultural-knowledge training for post-secondary administrative, teaching, admissions, and placement personnel
- Tenure and promotion based upon teaching quality rather than research and publishing

Work Place

- Appointment of women of color to corporate boards; hiring and promotion goals for women and men of color
- Equity training for managers
- In businesses, frequent self monitoring for race, ethnic, and gender representation at all levels
- Flexibility and tolerance for diversity as a part of the corporate culture

Whether in school or in the workplace, a strong commitment to racial and gender equity must be espoused and demonstrated by the CEO, president, or superintendent, and the top levels of their management.

These recommendations refer specifically to women and girls of color; however, similar measures should be taken to combat the underrepresentation of men and boys of color, too. For women of color, the elimination of ethnic discrimination is as inextricably tied to equity as is the elimination of gender bias.

In several instances equity training is recommended—for parents, educators, and managers. Parents begin to treat boys and girls differently from infancy. Boys are encouraged and reinforced for being more active and physically inquisitive than girls. Boys are exposed to more activities that relate to spatial conceptualization and manipulation than girls are, and are encouraged more to tinker with machines. Boys are permitted and reinforced for more risk taking behavior than girls.

These differences persist in school. Teachers have been observed giving positive reinforcement to girls for their behavior, but to boys for the substance of their school work. Even teachers who want to be and think they are gender fair, have been surprised to see their bias when videotaped (Sadker, 1988). Moreover, studies have shown African-American girls and boys, regardless of achievement, receive more negative reinforcement from teachers than do white students.

Equity training has been shown to have positive effects in reducing both gender and ethnic bias among parents and teachers. Equity training for managers and administrators in the workplace, as part of a plan that creates a business climate that welcomes and values ethnic diversity and gender differences, has also been demonstrated to be effective.

The future of the country depends upon the nation's courage to rectify a discriminatory educational system and an exclusionary workplace power structure that foster only mediocrity. It can be done, but only if a national will to utilize the talents of all people is created and maintained.

References

- Banks, M.E., & Ackerman, R.J. (1989). *Employment patterns for women in computer fields: Focus on women of color*. Unpublished paper, Brecksville V.A. Medical Center, Brecksville, OH.
- Beane, D. B. (1985). *Mathematics and science: Critical filters for the future of minority students*. Mid-Atlantic Center for Race Equity. Washington, DC: The American University.
- Edwards, C. E., & Irvine, J. J. (1987). Project MiCRO, prior student computer use. *Proceedings of National Educational Computing Conference '87*. Eugene, OR: International Council For Computers In Education.
- Edwards, C.E., & Irvine, J.J. (1985). Study of home computer use. Unpublished raw data.
- Gardner, A.L., Mason, C. L., & Matyas, M.L. (1989) Equity, excellence & just plain good teaching. *The American Biology Teacher*, 51(2), pp. 72-77.
- Green, G., & Epstein, R. (Eds.). (1988). *Employment and earnings*. U.S. Department of Labor, Bureau of Labor Statistics. Washington, DC: U. S. Government Printing Office.
- Hale-Benson, J. (1986) *Black children: Their roots, culture & learning styles*. Baltimore: The Johns Hopkins University Press.
- Irvine, J. J. (1986). *Black students and school failure*. Westport, CT: Greenwood Press
- Lenz, L. (Ed.) (1990). Voices of Chicago school reform. *Catalyst*, 2(2).
- Malcom, S., & Matyas, S. (1988). *Brilliant women for science, mathematics and engineering: Getting more than we deserve*. Unpublished document. Washington, DC: American Association for the Advancement of Science.
- Martinez, M. E., & Mead, N. A. (1988). *Computer competence: The first national assessment*. Princeton, NJ: Educational Testing Service.
- Matyas, M.L., & Malcom, S.M. (Convenors). (1987). American Association for the Advancement of Science. Draft summary. *Recommendations for action from the Conference Women in Science and Engineering: Changing Vision to Reality*. Office of Opportunities in Science, Washington, DC.
- National Education Association. (1990, June). Academic tracking. *Report of the NEA Executive Committee Subcommittee on Academic Tracking*. Washington, DC.
- Oaks, J. (1985). *Keeping track: How schools structure inequity*. New Haven: Yale University Press.
- Ornstein, A.C., & Levine, D.U. (1989). Social class, race, and school achievement: Problems and prospects. *Journal of Teacher Education*, 17-22.
- Orr, E.W. (1987) *Twice as less: Black English and the performance of black students in mathematics and science*. New York: Norton.
- Pelavin, S., & Kane, M. (1990). Report links high school mathematics to minority college enrollment. *Science Education News*, 8(7), pp.2-3.
- Sadker, M. (1988, Spring). Sex equity. Paper presented at a meeting of the Center for Women Policy Studies. Washington.
- Smey-Richman, B. (1989). *Teacher expectations and low-achieving students*. RBS Research and Development Project. Philadelphia.

- U.S. Department of Education, National Center for Educational Statistics. (1986). *Degrees and other formal awards conferred survey*. Washington, DC: U.S. Government Printing Office.
- U.S. Department of Education, National Center for Educational Statistics. (1987). *1986-1987 college completions in computer science*. Unpublished raw data.
- U.S. Department of Labor, Bureau of Labor Statistics. (1989). *Employed persons by detailed occupations, sex, race and Hispanic origin by industry and occupation* (Table 1). 1989 annual averages by detailed occupations. Unpublished.
- U.S. Department of Labor, Bureau of Labor Statistics. (1989). *Employed and experienced unemployed persons by detailed industry, sex, race and Hispanic origin* (Table 2). 1989 annual averages by detailed industries. Unpublished.
- U.S. Department of Labor, Bureau of Labor Statistics. (1983). *Employed and experienced unemployed persons by detailed occupation, sex, race, and Hispanic origin* (Table 30). 1983 annual averages from the current population survey. Unpublished tabulations.
- West, P. (1990, Sept. 26). Tracking hampers minorities' access to math, science careers, study finds. *Education Week*.

About the Author

Carol Edwards is currently with the Southern Coalition for Educational Equity, Inc. She earned her Bachelor's degree at Lake Forest College, and her Master's degree at Teachers' College, Columbia University.

Recent publications include:

- Edwards, C. (1988, Oct.). *Equitable computer education for girls and boys of color*, Center for Women Policy Studies.
- Edwards, C. (1988, Nov.). *Technology in schools—implications for students and teachers*, The Council of the Great City Schools.
- Edwards, C. *Project MiCRO, Integrating theory, research, and practice: How an intervention program in educational computing for middle schools, minorities & females meets challenge*.
- Edwards, C. (1990, April). *Assessing success in critical thinking skills: Project MiCRO and schools*, American Educational Research Association.
- Edwards, C. *The critical thinking skills lesson guide: Using microcomputer-based activities to teach skillful thinking*.

Ms. Edwards is currently directing the Project for the Retention and Increase of Minority Educators (PRIME) for the Southern Coalition for Educational Equity. The goal of PRIME is to identify and implement educational reform policies and practices that will increase the pool of teachers of color. Among her research interests are: the use of educational technology in school restructuring, the role of technology in enhancing career satisfaction among creative teachers of children of color, and increasing the equitable participation of girls and boys of color in creative and analytical uses of instructional technology.

III. STRATEGIES FOR CHANGE

Strategies for Involving Girls in Computer Science

Valerie A. Clarke

Deakin University, Geelong, Victoria, Australia

Abstract

The current shortage of computer scientists could be resolved by increasing the number of girls enrolling in both undergraduate and graduate accredited computer science programs. The major barriers preventing such an increase arise from the beliefs and expectations of both men and women regarding the abilities and interests of girls and boys in relation to computer science, and from the impact of these unquestioned expectations on interpersonal and organizational behaviours. This paper identifies thirteen barriers inhibiting the enrollment of girls, analyzes the origins of these barriers, and suggests practical strategies for overcoming them.

The Problem

In Australia, there is a shortage of qualified computer scientists, which is evident from the number of advertised job vacancies that remain unfilled, and from the higher salaries received by computer science graduates relative to those of other science graduates (Ridgeway, 1990). Within most computer science courses, girls are under-represented, accounting for less than a third of the enrollments. For example, at Deakin University, the proportion of girls enrolled in computer science declined from 30% in 1983 to 10% in 1986 and increased to about 30% in 1990 (Teague, 1990). Across Australian universities, women account for approximately 50% of undergraduate enrollments (Jones & Castle, 1989), but only for 25% of enrollments in accredited computer science courses (Kay, 1990). The situation is even less equitable in the U.K., where the proportion of girls enrolled in tertiary computer science courses declined from 26% in 1979 to 20% in 1980, to a low of 13% in 1985, before increasing slightly to 15% in 1989 (Eager, 1990). In the U.S., about a third of the students in computing and technology courses are women, but women account for a mere 15% of all high-tech professionals (Freundlich, 1989). An obvious way to redress the shortage of computer science graduates is to attract more girls into tertiary level computer science courses, and to encourage them to remain to undertake higher degrees.

Thesis

Extending and integrating the theoretical propositions of Bem (1981), Deaux (1984), and Deaux and Major (1987), it will be argued that it is not true that girls are no good at computing or that they are not interested in computing, but that it is true that both men and women believe that girls are no good at computing and believe that they do not like computing. Such beliefs are self-perpetuating, and difficult, but not

impossible, to change. These beliefs have their origins in the relatively well-developed, and often unconscious, gender-schema and computer-schema of students, parents, and teachers. Gender-schema organize the holder's expectations and beliefs along gender lines, defining appropriate attitudes, expectations, and behaviours for girls and boys, while computer-schema provide a set of expectations regarding the nature of computing, of the computing culture, and of the requisite skills and interests. These gender and computing schemata underlie a set of unquestioned assumptions about gender-related computing attitudes, interests, and behaviours. These assumptions are reflected in gender-based differences in the provision of encouragement, advice, and opportunities, which, in turn, promote the differential enrollments of girls and boys in school-based computing courses and college- or university-based computer science programs. Although both sets of schemata often arise from inaccurate beliefs, they are self-perpetuating. Many of the barriers responsible for the limited female participation in tertiary level accredited computer science programs arise from the unquestioned values, beliefs, and expectations inherent in these gender-related and computing-related schemata. Most of the strategies recommended to increase female enrollments involve changing these beliefs, assumptions and expectations, and/or the behaviours that arise from them. This thesis will be developed through the identification and analysis of a number of specific beliefs and problems, each of which will be followed by strategies to counter them.

Girls Are No Good at Computing or Computer Science

Problem: There is a general belief among many teachers, parents, and students that girls are no good at computing or computer science. Computers are seen as inherently mathematical, partly because they are often introduced into secondary schools by teachers of mathematics within the mathematics curriculum (Firkin, Davidson, & Johnson, 1985), or into tertiary institutions as part of the mathematics department (as at Deakin University), and partly because they are seen as highly efficient number crunchers. As girls are not expected to be good at mathematics, they are not expected to possess computing ability.

The origins of this belief need to be challenged as they reflect inaccurate perceptions of the nature of computers and of computer science, as well as inaccurate perceptions of the abilities of girls and boys. First, computers are not inherently mathematical. In fact, most work with computers involves manipulation of information and communication with people, which relies as much on verbal and interpersonal skills as on mathematical abilities. A great deal of work with computers uses applications software, which requires the capacity to read and understand the instructions provided in written manuals. Many of the tasks given to computer science graduates involve writing programs (which may be seen as a language skill), or working with people (which assumes interpersonal skills). For example, the primary role of a systems analyst is to enter an organization, find out about its organizational needs, and design a computing system that will meet those needs. The successful

completion of this task requires interpersonal skills, both to communicate with the people in the organization to ascertain their needs, and to work cooperatively with them to introduce a new or modified system.

The belief that girls are no good at mathematics originated in early studies of sex differences, such as those reviewed by Maccoby and Jacklin (1974), which concluded that boys outperformed girls on tests of mathematical ability. These conclusions were initially challenged by Fennema (1983), who demonstrated that apparent sex differences in mathematics ability were in fact based on measures of mathematical achievement, and merely reflected differences in the numbers and types of mathematics courses studied prior to taking the tests. Once mathematical experience was partialled out, most sex differences disappeared. Taking a different approach and using the studies which formed the basis of Maccoby and Jacklin's (1974) original conclusions, Hyde's (1981) meta-analysis demonstrated that sex only accounted for 1% of the variance in mathematical ability. More recently, Linn and Hyde (1989) have demonstrated that sex differences in quantitative abilities have declined since 1974, with recent studies yielding very few differences (an average effect size as low as $+0.05$ for the general population). The greatest sex differences occur in studies employing applications that involve sex-based differences in relevant experiences, and in studies of specialized groups (e.g., Benbow & Stanley, 1980). Focusing more specifically on studies of computing achievement, Hattie and Fitzgerald's (1987) meta-analysis found few substantial sex differences. Other researchers (Anderson, 1987; Linn, 1985) suggest that the nature and extent of reported sex differences reflect the selection of skills assessed. When tests focus on the technological aspects of computing, boys often perform better; but when they are more concerned with the role of communication, girls are more successful, being more willing to pay attention to detail and more competent at both writing and following instructions.

The practical problem is one which is common in psychological research (Denmark, Russo, Frieze, & Sechzer, 1988), in that small sex differences, which have been demonstrated to be statistically significant, have been treated as if they were substantive differences. Later these small differences have been quoted out of context and exaggerated both by the media and in secondary sources (Jacklin, 1989). In those cases where parents have read these exaggerated reports (e.g., Benbow & Stanley, 1980), they have accepted them and believed that their daughters' lack specific abilities, whereas parents who have not read these reports believed their sons' and daughters' abilities were equivalent (Eccles & Jacobs, 1986). Essentially, the small differences reported in the research have led to the development of sex-based differences in the attitudes and expectations of parents, which have, in turn, affected the expectations, subject choices, and performance outcomes of their sons and daughters.

Strategies: The most obvious solution to this problem is to widely publicize research findings demonstrating that the basis of the traditional beliefs in sex differences in mathematics and computing abilities need to be re-assessed, and to also

publicize reports of the increasing numbers of studies showing that girls perform equally with their male colleagues in computer science courses (e.g., Anderson, 1987; Clarke & Chambers, 1989; Fetler, 1985; Ivenstosch, Kersteen, & Linn, 1987; Linn, 1985), so that students, parents, and teachers will change their attitudes and expectations. Once people generally believe that girls are good at computer science and expect them to be as competent as boys (or more competent than boys), girls will respond by enrolling in these courses. The greatest obstacle to this common sense approach lies in the tendency of both the popular press and of academic journals (Rosenthal, 1979) to see sex differences as newsworthy and to be notably disinterested in non-significant research findings.

Another solution to this problem is to make computer science classes or courses a compulsory part of the curriculum at upper secondary or freshman level, so that girls can "discover" that they are good at using computers and enjoy using them. In a prototype study using this approach, Clarke and Chambers (1989) reported that women and men entering a compulsory first level tertiary computing course had very different expectations. The women had less previous computing experience, less positive attitudes towards computers, and expected to obtain lower grades than did their male colleagues, but the final course results demonstrated that there were no significant sex differences in achievement.

Within the research community, researchers need to be aware of the sex-based biases (Denmark, Russo, Frieze, and Sechez, 1988) underlying much of their research, and to design studies devoid of sex biases.

Sex Differences in Experience

Problem: There is a wealth of research data showing that boys gain more computing experience than do girls. They are more likely to have completed computing courses at secondary school (VCAB, 1988), to have enrolled in computing summer camps (Miura & Hess, 1984), to have used a greater variety of computing software while at school (Becker & Stirling, 1987; Clarke & Chambers, 1989; Hattie & Fitzgerald, 1987), to have had greater access to school computing resources in non-class time (Becker & Stirling, 1987; Clarke & Chambers, 1989), to own and use computers at home (Clarke, & Chambers, 1989; Miura, 1986), to belong to computer clubs (Clarke & Chambers, 1989; Chen, 1986; Culley, 1988), to have entered and won computing contests (Parker & Widmer, 1984), and to have been participants rather than on-lookers in video games arcades (Clarke, 1986; Kiesler, Sproull & Eccles, 1985).

Differences in experience lead to differences in opportunities to gain further experience. Students who have had greater access are more likely to be asked by teachers and peers to demonstrate their expertise, and hence further increase their computing experience at the expense of those lacking such experience (Fisher, 1984). In an Australian study of primary and secondary students, Chambers and Clarke (1987) showed that there were major differences in the reported class computing

experience of children within the same classes. These differences not only favoured boys, but also favoured students from higher social status homes and those from the majority cultural group. The introduction of additional computing resources exacerbated the initial group differences in experience, with those who already had more experience gaining the greatest benefit.

Experience using a variety of applications provides an opportunity to develop an understanding of many of the concepts involved in computer science (Bernstein, 1990), and leads to the development of positive attitudes toward computers (Chen, 1986), and feelings of competence in working with computers. Sex differences in attitudes and achievement disappear in those cases where girls are given the opportunity to gain a minimal level of relevant experience (Clarke & Chambers, 1989; Chen, 1986; Culley, 1988; Kay et al., 1986). Girls' lack of relevant experience is partly due to the nature of many computing environments, which, at best, they find unattractive, at worst, they find alienating.

Strategies: If lack of previous computing experience is seen as a major factor inhibiting the enrollment of girls in tertiary computer science programs, the most obvious solution is to increase access for all students, but particularly for girls. This can be done in several ways: first, by increasing the computing facilities so that all students have greater access to school and college resources; second, by introducing computers to girls in single-sex schools or single-sex classes to ensure access (Clarke, 1985; Culley, 1988); and third, by developing policies that allow girls and boys equal access to limited resources (Macrae, 1985) through the timetabling of girls-only computing classes or the allocation of particular resources to girls.

Perhaps more important than public access at school or college is the need for private access to computers: the opportunity to take a computer home to work alone or with a colleague. Many of the sex differences in experience, enthusiasm, and competence evident in group situations are less evident in private work. This is possibly due to the absence of the conflict in the public situation between the tendency to pay attention to the task and the tendency to pay attention to the other people present (Baron & Byrne, 1987). This model explains some interesting research findings reported by Huff (1990), whereby females were anxious using male sex-typed software, and males were anxious using female sex-typed software, but only when they were working in public. When given private access, the anxiety was reduced. Such findings suggest that it is important to provide women with the opportunity to have private access to computing resources, through borrowing programs or low interest loans to purchase computing equipment.

Access in a supportive environment is particularly helpful. Where computer labs have been introduced into student residences, these have resulted in increased computer access, positive reactions to the computers, and increased work-related interactions with fellow students (Freyd, Dennis, & Kinsella, 1990).

Girls Are Not Interested In Computers or Computer Science

Problem: Observations of the greater numbers of boys enrolling in computing courses and spending time in school computer centres and games arcades, together with students' responses to attitude items on questionnaires are often taken as "evidence" that girls are not interested in computers. A closer examination of the research on which these conclusions are based might lead to the more restricted statement that some girls may not be interested in engaging in some types of computing activities (video games, programming in BASIC), or in participating in some types of environments (games arcades, crowded terminal rooms, or microlaboratories), or in enrolling in some courses. Not only has the case been overstated and the research findings both exaggerated and over-generalised, but also most of the studies reflect particular assumptions about the nature of the computing culture, assumptions that may no longer be valid, being based on studies that describe the culture of the early 1980s (as described by Kiesler, Sproull, & Eccles 1985; Sproull, Kiesler, & Zubrow, 1987).

In reflecting on the nature of the computer culture, consider your own behaviour. How often do you inhabit male-dominated terminal rooms or school computer centres? How much of your leisure time do you spend in these places? How often do you queue for a turn to use a terminal? How often do you do battle with a mainframe computer which is constantly going off line? How often do you write programs in BASIC? How often do you play arcade-style games? How often would you respond "strongly agree" to statements like "I enjoy playing games on a computer" or "I find that using a computer is fun"? Even if you rarely do any of these things, you may spend many of your working hours using personal computers for multiple purposes, operating through highly diverse networks readily accessed from the relative privacy and tranquility of your office or home. Turning from our own behaviour to that of teenage girls, a few observations made casually at home demonstrate this point even further. My two teenage daughters would not be seen in a games arcade or a school computing centre after school and would clearly state that they are not interested in computers, but when they need a Macintosh for a school project, they are extremely competent in using a wide variety of software. When they feel like making greeting cards for friends, or playing games on the computer, they do not need assistance and enjoy engaging in their chosen computing activities. In fact they spend many hours, separately or together, working competently, productively, and happily with a computer. If they chose to enter the field of computer science, they would have the requisite experience, skills, and interests. If they were subjects in a typical study assessing interest in computers, the researchers would (incorrectly) conclude that they were not interested in computers or in computer science.

Strategies: At a practical level, recognise the fallacy of the belief that girls are not interested in computing, and seek to actively encourage their interests through the use of projects designed to appeal to them. At a research level, be aware of the limitations of research assessing sex differences (Denmark et al., 1988), research in which

findings based on limited samples of the possible range of computing activities and environments are being generalised to encompass all types of activities and environments. Recognise that male values are often treated as the norm, and that activities and interests preferred by females are often seen as either inferior, or as indicating lack of interest in the "real" business of computing. Design new projects to identify the types of activities in which girls and boys are interested, and the types of computing environments in which girls or boys enjoy working, so that both types of environments can be consciously created.

Gender-Related Behaviours and Expectations of Teachers

Problem: Reports of classroom computing activities provided by teachers show few sex differences in student computer use in class (Becker & Stirling, 1987; Hattie & Fitzgerald, 1987). However, students' reports of these activities show sex differences favouring boys (Chambers & Clarke, 1987), while observations of classroom behaviours show that boys gain the greater share of the resources: teachers are more likely to call on boys to answer questions or operate computers, teachers respond more immediately to the requests made by boys, and teachers often provide answers to boys' questions about problems in situations where they take over and complete the task for girls (Carmichael et al., 1985; Culley, 1988; Firkin et al., 1985). The differences in the research findings reflect a difference in the choice of research technique. If the researchers question teachers, there are few sex differences. If the researchers question students or observe classrooms there are considerable sex differences. This does not imply that teachers are lying or deliberately misleading researchers, but rather that they are unaware of the extent to which they have highly developed gender-based expectations and responses which influence their daily interactions in the classrooms. Studies which have monitored teachers' behaviour and drawn these unconscious gender-based behaviours to their attention have reported modifications in these behaviours (Whyte, 1984).

Strategy: Teachers need to become aware of their gender-schema and the influence of these schema on their classroom behaviours. This can be achieved through the publication of research findings, or, more directly, through providing teachers with video recordings of their classroom interactions.

Teaching Style

Problem: Introductory courses in computer science (whether at secondary or tertiary level) alienate girls by assuming a background which they do not have and/or by presenting material in a manner or context which they find difficult or unusual (Edwards, 1990). In many instances, the teaching style and problem contexts have been developed by male teachers and professors who are unaware that females may find their approach incompatible with their interests or preferred working style. Within computing environments males and females often use different learning strategies. Girls are reluctant to experiment with new technology, while boys are eager

to demonstrate their mastery, showing little concern for the consequences of incorrect actions (Lovegrove & Hall, 1987). Girls use reproductive strategies, while boys use constructive ones. Girls are less autonomous, being more likely to seek help from teachers and lecturers, while boys seek their own solutions. Girls retain strategies which have previously proved to be successful, while boys seek new ones (Iventosch, Kersteen, & Linn, 1987; Kersteen, Linn, Clancy, & Hardyck, 1986). Girls and boys adopt different approaches to solving programming problems (Turkle & Papert, 1990).

Strategies: Encourage teachers to recognize the existence and validity of different approaches to computer science problems and to accept styles more popular among female students as being equally valid as those preferred by males. Adopt teaching strategies that are compatible with the learning styles preferred by girls as well as those preferred by boys. Choose examples and problem contexts that are equally appealing to males and females. Encourage teachers to recognise the students' level of expertise (or lack of expertise) and allow time to explain both computing jargon and technical concepts.

Gender-Related Behaviours and Expectations of Parents

Problem: Parents expect that their sons will be interested in computers and good at computing, whereas their daughters will be disinterested in computers and not interested in using them. These beliefs are reflected in their greater willingness, first, to buy computers for their sons rather than for their daughters (Acorn, 1984); second, to enroll their sons in computing summer camps (Miura & Hess, 1984); third, to encourage their sons' interests in computing (Lockheed & Frakt, 1984); and finally, to assist their sons with school computing projects (Carmichael et al., 1985). Given that one of the most important factors predicting children's interest in computing is their perceptions of their parents' desires for them to be interested in computing (Clarke, 1986; Firkin et al., 1985), sex-based differences in parental expectations for their children will result in the children incorporating these expectations into their gender-schema, computer-schema, and self-schema, which will, in turn, influence the children's beliefs regarding their own interests and behaviours and those of their peers.

Strategy: Like teachers, parents need to be provided with the information and opportunities to become aware of their gender-schema and of the fallacy of gender-based assumptions about interests and abilities, and encouraged to treat their sons and daughters equally. Part of their lack of concern arises from the generational lag, from their lack of awareness of their limited view of the role of modern technology. As they managed to grow up without computers, many parents (and teachers) fail to see the importance of computers in the future lives of their children (and students). They see playing with computers as an optional extra, rather than an important part of education; something which is rapidly being added to (or replacing) the traditional stalwarts of reading, writing, and arithmetic.

Sex-Based Differences in Needs For Relevance

Problem: Males and females have different needs (Maccoby & Jacklin, 1974). Whereas females have a strong need for relevance, males are often happy to tinker for the sake of tinkering (Whyte, 1984). Whereas boys find intrinsic interest in a task, girls often seek an external justification. When asked to undertake a particular assignment, girls often ask why it needs to be done, whereas boys will be more likely to complete it because it is there and is intrinsically challenging. Many girls see the content of school computing courses as irrelevant to their private lives or their future careers (Lovegrove & Hall, 1987). These observations are consistent with meta-analytic reviews that suggest that the major sex difference in interests in mathematics and science is in its perceived usefulness (Linn & Hyde, 1989), a factor that could conceivably account for differential enrollments in both secondary and tertiary computing courses.

Strategies: Recognise girls' needs for relevance by introducing computer science concepts within a socially relevant context rather than as a set of abstract skills which appear to have little to do with daily living. Use projects where girls can work in groups and where the immediate use of the developing skills is evident. Rather than talking abstractly about computer science concepts, initially introduce them through the use of software packages (Bernstein, 1990). Make explicit the importance of computing skills both in the job market and in our daily lives.

Computing is Inherently Masculine

Problem: It is commonly believed that all computer users and computing experts are male, and therefore computing careers are for men, but not for women. Certainly, men predominate among school computing teachers, college and university computing lecturers, keynote speakers at computer conferences, educational computing consultants, computer store personnel, guest speakers in the field of computing, active roles both in films and videos about computers, active roles in pictures in computer magazines, and as users of computers at home (Clarke, 1986, 1990). However, the inference that this obvious male dominance is reflected in widespread sex-typing of computing occupations and the consequent alienation of girls from computing careers is an inference that must be questioned. First, the extent to which students see computing as sex-typed depends partly on the social context in which they are initially introduced to computers. Girls in a single-sex school are likely to sex-type computing as a female activity, whereas those in a co-educational school are more likely to sex-type it as a male activity (Clarke, 1985). Second, findings from a recent survey of Australian adults suggest that sex-typing may not be as great or as pervasive as we might be led to expect (Clarke, 1989). Although the major computing occupations included in the study were sex-typed (data entry operator as female, and computer programmer and computer salesperson as male), such sex-typing was minimal among women under 30 year of age and was most marked among men over 50 years of age. It appears that these beliefs may influence the career choices of girls indirectly through

the influence of fathers, male computing teachers, and career advisers, but they have less direct effect on these choices.

However, the masculine image of computing appears to be less of a problem than the absence of mentors for females aspiring to academic or business careers in computer science. Due to the shortage of female role models, there are few women to show them how to cope with the cultural and sociological barriers, and few fellow female students with whom to work and socialise, leading to feelings of isolation (Freundlich, 1989). It is not the presence of men and the masculine image that turns girls away, but the absence of women and of female colleagues with whom to share their experiences.

Strategies: To change the male image of computing, include equal numbers of men and women in active roles in television and magazines presentations. Give successful women a higher profile so that men and women believe that women use computers, and women expect that they personally should both use them and embark on careers in computer science. Increase the numbers of women who are teaching computing in schools, colleges, and universities to provide more female role models, colleagues, and mentors.

It Is a Woman's Problem

Problem: It is often believed that the best way to attract more women into computer science is to focus on changing the attitudes and expectations of women. However, the greatest gain may be made by focusing on the attitudes of men. After all, men hold the positions of power within schools, colleges, and universities (Jones & Castles, 1990). Men hold the sex-typed views of computing (Clarke, 1989). It is often girls' fathers, male teachers, and male career advisers who encourage girls to take non-computing subjects and courses.

Strategy: Aim to change the beliefs, attitudes, and expectations of men as well as of women. Once girls have selected the appropriate subjects and courses, it is then essential to draw on the resources of male mentors who are willing to assist young female students and junior academics to progress through tertiary level computing courses and into computing careers, both within and outside the training institutions.

Social Isolation

Problem: The image of a computer scientist is often confounded with the image of the "hacker" who spends all his waking hours working alone with a computer (Turkle, 1984). Although there is a negative correlation between computer use and social interaction (Fluck, 1990), the direction of this relationship has not been established. However, this isolationist image of computer-users has more limited appeal to females.

Strategy: Dispel the myth that the hacker is a typical computer scientist through provision of more accurate information as to the range of work in which computer scientists are involved. Recognise girls' need for social interaction by encouraging

group work and class discussion, and by arranging computer rooms to facilitate interpersonal communication. Particularly at secondary and college level, provide a wide variety of computing activities. Either in addition to traditional BASIC programming, or in lieu of programming, include work using Logo, Lego-Logo, spreadsheets, databases, word processors, multi-media presentations, arcade games, and telecommunications to create an awareness of the diverse applications of computers. Emphasise the interpersonal nature of many of these activities. Foster cooperation rather than competition between students by encouraging students to discuss their ideas with each other.

Computing Is Inherently Technological

Problem: A heavy emphasis on hardware and the technical aspects of computing alienates girls not only from enrolling in computer science courses, but also from using computers as tools in their studies and daily lives. It is assumed that to use a computer it is essential to understand its technical features. However, computers are tools which are used to complete tasks. There is no need to understand the technical features of the composition of the lead in a pencil to use the pencil effectively to write a beautiful piece of poetry, nor is it necessary to understand the nature of the transmission of a car to drive it efficiently and safely. As Papert (1985) argues, computing is a "culture" not a "technology." What is done with computers is more important than how they are built. To be a highly sophisticated user, it is not essential to be a technician.

Strategy: De-emphasise the technical side of computing, direct attention to the cultural context in which computers are used, and emphasise the diversity of its applications.

Timetable

Problem: Many girls are "prevented" from studying computer science by timetables which schedule computer science against other subjects, which to girls have a higher priority. At college, it may be less a problem of timetable clashes than of the times selected. Female students often avoid evening classes, either because they do not like wandering around the campus after dark, or fear for their safety on public transport. This timetable problem may arise from an unquestioned assumption that girls do not wish to enroll in computing, or from a lack of awareness of the constraints which the timetable places on female students.

Strategy: Both secondary and tertiary institutions need to question the unquestioned assumptions underlying their timetables and carefully monitor their timetables to ensure that males and females enjoy equal access both to computer science courses and to the prerequisite subjects.

Prerequisites

Problem: Often students reach tertiary level only to "discover" that they do not have the appropriate prerequisites (Edwards, 1990). Early subject choices are often

made in the absence of appropriate advice, or on the advice of counsellors who may respond differently to male and female students with equivalent qualifications and experience (Kahn & Schroeder, 1980). Many career teachers are unaware of the prerequisites for computer science, or of the career opportunities available (Lovegrove & Hall, 1987).

Strategy: Recognise the importance of early subject choices and ensure that all students are aware of the implications of selecting or avoiding specific subjects. Offer girls the same advice that is being offered to boys who have equivalent academic abilities and interests.

Conclusion

There is insufficient substantial evidence to support beliefs that there are innate differences in the computing interests or capacities of girls and boys. The computing culture is socially constructed and continually changing. If we wish to involve more girls in this culture and attract them to careers in computer science, it is essential to recognise that their needs and values may be different from those of their male colleagues, to accept the validity of these values, and to design courses and programs that not only accommodate these differences, but also recognise and capitalise on the available diversity of interests and skills.

References

- Acorn (1984). Computer research notes. [mimeo.]
- Anderson, R.E. (1987). Females surpass males in computer problem solving: Findings from the Minnesota computer literacy assessment. *Journal of Educational Computing Research*, 3 (1), 39-51.
- Baron, R.A. & Byrne, D. (1987). *Social psychology: Understanding human interaction*. (5th Edition). Sydney: Allyn and Bacon Inc..
- Becker, H.J. & Stirling, C.W. (1987). Equity in school computer use: National data and neglected considerations. *Journal of Educational Computing Research*, 3(3), 289-311.
- Bem, S.L. (1981). Gender schema theory: A cognitive account of sex typing. *Psychological Review*, 88, 354-364.
- Benbow, C.P. & Stanley, J.C. (1980). Sex differences in mathematical ability: Fact or artifact? *Science*, 210, 1262-1264.
- Bernstein, D. (1990). In search of gender-free paradigms for computer science education: A new introduction to computer science. National Educational Computing Conference, Nashville, Tennessee, 25-27 June.
- Carmichael, H.W., Burnett, J.D., Higginson, W.C., Moore, B.G. & Pollard, P.J. (1985). *Computers, children and classrooms: A multisite evaluation of the creative use of microcomputers by elementary school children*. Final report of a project completed under contract. Ontario: Ministry of Education.

- Chambers, S.M. & Clarke, V.A. (1987). Is inequity cumulative? The relationship between disadvantaged group membership and students' computing experience, knowledge, attitudes and intentions. *Journal of Educational Computing Research*, 3(4), 495-517.
- Chen, M. (1986, April). Gender and computers: The beneficial effects of experience and attitudes. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco.
- Clarke, V.A. (1985). Computing in a social context. In K. Duncan & D. Harris (Eds.) *Proceedings of the 4th World Conference on Computers in Education*. IFIP TC3 and AFIPS, Norfolk, Virginia, pp. 832-838.
- Clarke, V.A. (1986). Computing in a social context: Gender differences in participation and achievement. Doctoral dissertation, Deakin University, Geelong, Victoria, Australia.
- Clarke, V.A. (1989). Occupational sex-typing: A declining problem in Australia. *Psychological Reports*, 65, 1011-16.
- Clarke, V.A. (1990). Sex differences in computing participation: concerns, extent, reasons and strategies. *Australian Journal of Education*, 34(1), 52-66.
- Clarke, V.A. & Chambers, S.M. (1989). Gender-based factors in computing enrollments and achievement: Evidence from a study of tertiary students. *Journal of Educational Computing Research*, 5, 409-29.
- Culley, L. (1988). Girls, boys and computers. *Educational Studies*, 14(1), 3-8.
- Deaux, K. (1984). From individual differences to social categories: An analysis of a decade's research on gender. *American Psychologist*, 39, 105-116.
- Deaux, K. & Major, B. (1987). Putting gender into context: An interactive model of gender-related behaviour. *Psychological Review*, 94, 369-389.
- Denmark, F., Russo, N.F., Frieze, I.H. & Sechzer, J.A. (1988). Guidelines for avoiding sexism in psychological research: A report of the ad hoc committee on nonsexist research. *American Psychologist*, 43, 582-585.
- Eager, C.J. (1990). Girls and computing: An overview. Paper presented at the *IFIP Fifth World Conference on Computers in Education*. Sydney: Australia, 9-13 July.
- Eccles, J.S. & Jacobs, J.E. (1986). Social forces shape math attitudes and performance. *Signs*, 11, 367-389.
- Edwards, C. (1990). Implications of the computer culture for women of color. Paper presented at the Pre-Conference Workshop: In Search of Gender-Free Paradigms for Computer Science Education, National Educational Computing Conference, Nashville, Tennessee, 24-28 June.
- Fennema, E. (1983). Success in mathematics. In M. Marland (Ed.), *Sex differentiation and schooling*. London: Heinmann Educational Books.
- Fetler, M. Sex differences on the California statewide assessment of computer literacy. *Sex Roles*, 13, 181-92.
- Firkin, J., Davidson, M. & Johnson, L. (1985). *Computer culture in the classroom*. Melbourne: Victorian Institute of Secondary Education.

- Fisher, G. (1984). Access to computers. *Computing Teacher*, 11(8), 24-7.
- Fluck, A.E. (1990). The social effects of new technology in schools - the SENTIS report. In McDougall, A. & Dowling, C. (Eds.), *Computers in Education: Proceedings of the IFIP TC 3 Fifth World Conference on Computers in Education - WCCE 90*, Sydney Australia, pp. 365-368.
- Freundlich, N. (1989). Making science more seductive to women on campus. *Business Week*. 28 August.
- Freyd, P., Dennis, C. & Kinsella, T. (1990, June). Computer labs in college residences: Opportunities for informal learning—especially for women and minorities. *National Educational Computing Conference Proceedings*, Nashville, Tennessee, pp. 287-292.
- Hattie, J. & Fitzgerald, D. (1987). Sex differences in attitudes, achievement and use of computers. *Australian Journal of Education*, 31(1), 3-26.
- Hyde, J.S. (1981). How large are cognitive gender differences? A meta-analysis using w^2 and d . *American Psychologist*, 36, 892-901.
- Huff, C. (1990, June). Expectations and gender differences in computer use. Paper presented at the Pre-Conference Research Workshop: In search of gender-free paradigms for computer science education, National Educational Computing Conference, Nashville, Tennessee.
- Iventosch, L., Kersteen, Z.A. & Linn, M.C. (1987). An exploration of gender-related study skill differences in computer science. Paper presented at the Annual Meeting of the American Educational Research Association. Washington, D.C., April.
- Jacklin, C.N. (1989). Female and male: Issues of gender. *American Psychologist*, 44, 127-133.
- Jones, J. & Castle, J. (1990). Women in higher education—changes in the '80s? *The Australian Universities' Review*, 32 (2), 6-8.
- Kahn, S.E. & Schroeder, A.S. (1980). Counsellor bias in occupational choice for female students. *Canadian Counsellor*, 14, 156-9.
- Kay, J. (1990, July). Computer equity: Girls, women and computers. Presentation at the Fifth World Conference on Computers in Education. Sydney, Australia.
- Kay, J., Collins, P., Lublin, J., Poiner, G., Prosser, M., Bishop, R., & Watson, K. (1986). *An investigation of the status of women at early stages of professionally accredited tertiary computer science and data processing programmes*. Sydney: University of Sydney, Basser Department of Computer Science.
- Kersteen, A., Linn, M., Clancy, M., & Hardyck, C. (1986). Previous experience and learning of computer programming: The computer helps those who help themselves. Paper presented at the Annual Meeting of the American Educational Research Association. San Francisco.
- Kiesler, A., Sproull, L.S. & Eccles, C.U. (1985). Pool halls, chips, and war games: Women in the culture of computing. *Psychology of Women Quarterly*, 9(4), 451-63.
- Linn, M. (1985). Gender equity in computer learning environments. *Computers and Social Sciences*, 1, 19-27.

- Linn, M.C. & Hyde, J.S. (1989). Gender, mathematics, and science. *Educational Researcher*, 18(8), 17-19, 22-27.
- Lockheed, M.E. & Frakt, S.E. (1984). Sex equity: Increasing girls' use of computers. *Computing Teacher*, 11(8), 16-18.
- Lovegrove, G. & Hall, W. (1987). Where have all the girls gone? *University Computing*, 207-210.
- Maccoby, E.E. & Jacklin, C.N. (1974). *The psychology of sex differences*. Stanford: Stanford University Press.
- Macrae, K. (1985). No boys to bug us . . . The gender issue: First hesitant steps. In B. Rasmussen (Ed.), *The information edge: The future for educational computing: Proceedings of the Third Australian Computer Education Conference* (pp. 67-79). Brisbane: Computer Education Group of Queensland.
- Miura, I.T. (1986). Understanding sex differences in middle school computer interest and use. Paper presented at the Annual Meeting of the American Educational Research Association. San Francisco.
- Miura, I.T. & Hess, R.D. (1984). Enrollment differences in computer camps and summer schools. *Computing Teacher*, 11(8), 22.
- Papert, S. (1985). Computer criticism Vs. technocratic thinking. *Logo85 theoretical papers*. Cambridge, MA: Massachusetts institute of Technology, 53-67.
- Parker, J. & Widmer, C. (1984). Some disturbing data: Sex differences in computer use. Paper presented at the Sixth Annual Educational Computing Conference. Dayton, OH.
- Ridgeway, G. (1990). *Computing/mathematics at Deakin University*. Geelong: Deakin University.
- Rosenthal, R. (1979). The "file drawer problem" and tolerance for null results. *Psychological Bulletin*, 3, 638-641.
- Sproull, L., Kiesler, S., & Zubrow, D. (1987). Encountering an alien culture. In S. Kiesler & L. Sproull (Eds.), *Computing and change on campus*. Cambridge: Cambridge University Press.
- Teague, J. (1990). Unpublished statistical tables of enrollments in Deakin University computer science courses. Geelong: Deakin University.
- Turkle, S. (1984). *The second self: Computers and the human spirit*. NY: Simon & Schuster.
- Turkle, S. & Papert, S. (1990). Epistemological pluralism: Styles and voices within the computer culture. Unpublished paper. MIT.
- Victorian Curriculum Advisory Board. (1988). [Statistics provided by VCAB.]
- Whyte, J. (1984). Observing sex stereotypes and interactions in the school lab and workshop. *Educational Review*, 36(1), 75-86.

About the Author

Valerie Clarke is currently with the department of Psychology, Faculty of Social Sciences, at Deakin University in Geelong, Victoria, Australia. She earned a B.A. with honors at Melbourne University, an M.A. at Melbourne University, and a Ph.D. at Deakin University. She is a member of the Australian Psychological Society, and a Foreign Affiliate of the American Psychological Association.

Recent publications include:

- Clarke, V.A. (1990). Sex differences in computing participation: Concerns, extent, reasons and strategies. *Australian Journal of Education*, 34 (1), 52-66.
- Clarke, V.A. (1990). Girls and computing: Dispelling myths and finding directions. In McDougall, A. (ed.) *Proceedings of the 5th World Conference on Computers in Education*. Amsterdam, IFIPTC 3 & AFIPS 53-58.
- Clarke, V.A. & Chambers, S.M. (1989). Gender-based factors in computing enrollments and achievement: Evidence from a study of tertiary students. *Journal of Educational Computing Research*, 5 (4), 409-429.
- Clarke, V.A. (1989). Occupational sex-typing: A declining problem in Australia. *Psychological Reports*, 65, 1011-1016.
- Chambers, S.M. & Clarke, V.A. (1987). Is inequity cumulative? The relationship between disadvantaged group membership and students' computing experience, knowledge, attitudes and intentions. *Journal of Educational Computing Research*, 3 (4), 493-516.

In 1990 she won the Deakin University Foundation Award for Excellence in Teaching. She has two areas of research interest: the involvement of more girls in computer science and computer courses at all educational levels, and health psychology. In relation to the latter she is an Academic Associate of the Centre for Behavioural Research in Cancer at the Anti-Cancer Council of Victoria.

A New Introduction to Computer Science

Danielle R. Bernstein
Kean College of New Jersey

Research has shown that previous experience and feelings of self-efficacy are major predictors of success in computer science courses (Hill, Smith & Mann, 1987; Konvalina, Wileman & Stephens, 1983). Although mathematics ability also correlates with success in computer science courses (Butcher & Muth, 1985; Campbell & McCabe, 1984; Whipkey, 1984) or computer usage (Egan, 1988), experience and self-efficacy can be analyzed independently of mathematics proficiency.

Self-efficacy with computers can be defined as the feeling that one is in control of the machine and can make a difference in the operation of the machine. This factor differs between men and women and may be a cause of women's lower level of achievement in computing. As a group, women rate themselves lower than men for perceived self-efficacy on computers (Dambrot, Watkins-Malek, Silling, Marshall & Garver, 1985; Lockheed, 1985; Miura, 1987; Ogozalek, 1989).

How do computer users get this feeling of self-efficacy? In many cases, previous experience with computers leads to perceived feelings of self-efficacy (Kersteen, Linn, Clancy, & Hardyck, 1988). In computing classes, students are encouraged to engage in free, unfettered exploration, something that cannot be imagined in a chemistry or biology laboratory. A great deal of experience in computing is the result of self-initiated investigations outside of class. How can we offer women that same experience?

A Different Approach

While men may be passionate about computers, women use computers to solve problems (Gerver, 1989; Markoff, 1989). Gerver explains that women have a more practical inclination and look at computers as tools. When women fail to see indications that computers are efficient tools, they may lose interest. However, when men and women use computers as tools to solve problems, both groups perform equally well and like using computers equally (Bernstein, 1990a; Pullman & Parsegian, 1987).

Turkle (1984) explains the difference in approach as a difference between hard and soft mastery. Hard mastery involves making a plan and conceiving a program as a whole. With soft mastery, things are not done by advance planning, but through negotiation and experimentation. In her studies with children, she infers that girls are soft masters and boys are hard masters.

A New Introduction to Computer Science

Currently, most high school students are introduced to school computing via BASIC programming. Mastery of BASIC leads to more procedural programming,

usually in Pascal. In college, procedural programming is preceded by an emphasis on system and program design in a step-by-step hierarchy of functions. Enabling women to feel confident and in control of a computer suggests a new curriculum paradigm for computer science education: software packages as an introduction to computing.

Using software packages instead of procedural programming as an introduction to computer science would have several immediate effects. Students would do something functional immediately. Women, who perceive computers as tools rather than as toys, would see the purpose of computers. With software packages, initial success brings immediate gratification. Exploration is easier and more natural with packages than with procedural programming languages. Group work, preferred by female students, can be fashioned more spontaneously around packages. In addition, software packages are less tied to the mathematics curriculum.

Software packages can be employed in many areas in high school. Desktop publishing can produce artwork, graphic design, newspapers, and magazines. Spreadsheets can help run a business (including the business of extracurricular activities), illustrate economic principles, and produce graphs and charts. Database management systems can classify objects and entities, and then retrieve specific information based on conditions to produce "Yellow Pages" telephone books and categorization in biology and social sciences.

But Is It Computer Science?

Software packages can provide an introduction to computer science at the college level superior to that provided by procedural languages. We need to reexamine the tenet that software packages are not computer science. Teaching sophisticated applications of software packages can illustrate and reinforce computer concepts such as files, records, fields, memory, secondary storage, Boolean operations, and the format versus the content of variables. These topics can be examined without the overhead of extensive program planning or syntax problems than can get in the way for a beginner. Students may then be able to transfer these concepts to procedural programming successfully.

Shinners-Kennedy (1986) points out that using spreadsheets to teach computer science can illustrate the dynamic nature of the computer, something that traditional teaching methods cannot do. At any point, the student's terminal displays an accurate representation of the current state of the machine. Shneiderman (1986) also appreciates that spreadsheets, in particular, may be a useful representation of rule-based systems, array computation, and data structures.

However, there may also be a counter trend in computer science education. Some colleges are maintaining that they will soon not teach introductory computer science but will expect students to start college with computer literacy skills (as yet undefined) gained in high school (Myers, 1989; Taylor, 1989). Taylor states, "the era is not far away in which entering students will be tested for computer science proficiency as they are in mathematics and English and then channeled in remedial levelling courses if indicated."

Dijkstra (1989) proposed that the introductory programming course should be turned into a course in formal mathematics. This proposed course should use an unimplemented programming language "so that students be protected from the temptation to test their programs" (emphasis mine). Such an approach would further diminish the number of computer science majors and discourage those students who want to see, tinker, experiment, and interact with computers in order to understand principles.

Not Without Problems

The use of software packages as an introduction to computer science in high school or college is not without practical problems. Personal computers with more memory and hard disk space are required. Application software packages such as spreadsheets and database management systems are more expensive than programming languages. Educational versions of commercial software are afflicted with restricted size and functionality; they may be able to solve only small, unrealistic problems. For example, the educational version of dBase III Plus can only handle 31 records. No matter how much an instructor stresses that the commercial version of dBase III Plus can handle a virtually unlimited number of records, students may have a difficult time picturing the practical uses of a database management system.

In contrast, BASIC interpreters and Pascal compilers are inexpensive. They are usually available on time-sharing systems, which relieves the pressure for personal computer laboratories.

Future Work

I have designed and taught an advanced course, Conceptual Understanding of Software Packages (Bernstein, 1990b). Though this course requires much previous knowledge from students, it illustrates that software packages have a place in computer science education. The next step is to design a course introducing computer science fundamentals using software packages.

The teaching of software concepts has paralleled the advances in software development. As functional software has moved away from the details of the hardware, there has been a cry that computer science is being watered down. But each step has encouraged new people to use computers. Serious conceptual understanding of application packages will continue this trend.

References

- Bernstein, D. (1990a). Understanding spreadsheets: Effects of power users' learning style and computer training of performance and mental model acquisition. (Doctoral dissertation, Rutgers University, New Brunswick, NJ). *Dissertation Abstract International*, in press.
- Bernstein, D. (1990b). Conceptual understanding of software packages. In *Proceedings of the National Education Computing Conference* (in press). Eugene, OR: International Society of Technology in Education.

- Butcher, D., & Muth, W. (1985). Predicting performance in an introductory computer science course. *Communications of the ACM*, 27(11), 263-268.
- Campbell, P. & McCabe, G. (1984). Predicting the success of freshmen in a computer science major. *Communications of the ACM*, 27(11), 1108-1113.
- Dambrot, F., Watkins-Malek, M., Silling, S., Marshall, R. & Garver, J. (1985). Correlates of sex differences in attitudes toward and involvement with computers. *Journal of Vocational Behavior*, 27, 71-86.
- Dijkstra, E. (1989). On the cruelty of really teaching computer science. *Communications of the ACM*, 32(12), 1397-1414.
- Egan, D. (1988). Individual differences in human-computer interaction. In M. Helander (Ed.), *Handbook of Human-computer Interaction* (pp. 543-567). North-holland: Elsevier.
- Gerver, E. (1989). Computers and Gender. In T. Forester (Ed.), *Computers in the Human Context*, pp. 481-501. Cambridge, MA: MIT.
- Hill, T., Smith, N. & Mann, M. (1987) Role of efficacy expectations in predicting the decision to use advanced technologies: The case of computers. *Journal of Applied Psychology*, 72, 307-313.
- Kersteen, Z., Linn, M., Clancy, M. & Hardyck, C. (1998). Previous experience and the learning of computer programming: The computer helps those who help themselves. *Journal of Educational Computing Research*, 4(3), 321-333.
- Konvalina, J., Wileman, S. & Stephens, L. (1983). Math proficiency: A key to success for computer science students. *Communications of the ACM*, 26(5), 377- 382.
- Lockheed, M. (1985). Women, girls and computers: A first look at the evidence. *Sex Roles*, 13(3/4), 115-122.
- Markoff, J. (1989, February 13). Computing in America: A masculine mystique. *New York Times*, pp. A1, B10.
- Miura, I. (1987). The relationship of computer self-efficacy expectations to computer interest and course enrollment in college. *Sex Roles*, 16(5/6), 303-311.
- Myers, J. P. (1989). The new generation of computer literacy. In R. Barrett & M. Mansfield (Eds.), *Conference Proceedings of SIGCSE* (Special Interest Group on Computer Science Education of the ACM). pp. 177-181. New York: ACM.
- Ogozalek, V. (1989). A comparison of male and female computer science students' attitudes toward computers. *SIGCSE Bulletin* (Special Interest Group on Computer Science Education of the ACM), 21(2), 8-14.
- Pullman, H. & Parsegian, E. (1987). Sex differences in attitudes toward computers. Presented at the 8th National Educational Computing Conference, Philadelphia.
- Shinners-Kennedy, D. (1986). Empirical studies of programmers: The territory, paths, and destinations. In J. Little & L. Cassel (Eds.), *Conference proceedings of SIGCSE* (Special Interest Group on Computer Science Education of the ACM) pp. 264-270. New York: ACM.
- Shneiderman, B. (1986). Empirical studies of programmers: The territory, paths, and destinations. In E. Soloway and S. Iyengar (Eds.), *Empirical studies of programmers*, pp. 1-12. Norwood, NJ: Ablex.

- Taylor, H. & Mounfield, L. (1989). The effect of high school computer science, gender, and work on success in college computer science. In R. Barrett & M. Mansfield (Eds.), *Conference proceedings of SIGCSE* (Special Interest Group on Computer Science Education of the ACM) pp. 195-198. New York: ACM.
- Turkle, S. (1984). *The second self: Computers and the human spirit*. New York: Simon and Schuster.
- Whipkey, K. (1984). Identifying predictors of programming skill. *SIGCSE Bulletin* (Special Interest Group for Computer Science Education of the ACM), 16(4), 36-42.

About the Author

Danielle R. Bernstein is an associate professor of computer science at Kean College in New Jersey. She earned a B.A. in mathematics and economics at Brooklyn College, an M.S. in applied statistics at Purdue University, an M.S. in computer science at Rutgers University, and a Ph.D. in information science at Rutgers University.

- Bernstein, D. (1990). *Understanding spreadsheets: Effects of computer training on mental model acquisition*. Proceedings of the American Society for Information Science, 164-172.
- Bernstein, D. (1990, January). *Understanding spreadsheets: Effects of power users' learning style and computer training on performance and mental model acquisition*. Ph.D. dissertation, Rutgers University.
- Bernstein, D. (1989). *Learning styles of computer users*. Proceedings of the National Educational Computing Conference, 268-272.
- Bernstein, D. (1988). *Using new software: Caution and adventure*. Findings. Union, NJ: Kean College.

At Kean College, Ms. Bernstein teaches courses on business programming, database management systems, and microcomputer applications. Previously, she was a member of the technical staff, and a supervisor at Bell Laboratories. Her Ph.D. research was on the effect of training methods and learning styles of computer users on their achievement and feelings about computing. She has expanded that research to include gender differences in approaches to computing and its implication for computer science education. Currently, she is designing and developing a course to introduce computer science fundamentals using software packages.

Restructuring Departments for Equality

Henry Etzkowitz

SUNY Purchase and Columbia University

Carol Kemelgor

New York University

Michael Neuschatz

American Institute of Physics

Brian Uzzi

SUNY Stony Brook

Most studies of women in science and engineering use individual level data and matched samples to determine the effects of gender on careers. Typically, sociologists compare women scientists with men of the same academic background (Cole and Zuckerman, 1987). These studies have produced varied findings on the effects of marriage and children on the research productivity of women. Some researchers find a positive effect, others a negative effect, and still others no effect (Long, forthcoming). We call these contradictory findings the "conundrum of women in science."

Even if this conundrum could be resolved, it would not change the reason that matched samples have to be used in the first place in these studies: the small number of women in most fields of engineering and science. This most obvious finding, about which there is no disagreement, has brought forth little consensus on what to do about it. Most analyses of the paucity of women in science focus on the so-called "pipeline" and the negative environmental factors that reduce the number of women with the background to embark on a scientific career (Widner, 1988). Lack of mathematics training at the junior high school level and even preschool attitudes that identify the scientific role with male status have been identified (Mulkey, 1989). However, even given these disadvantages, a significant number of women receive B.A.s and even Ph.D.s in science. Nevertheless, fewer pursue careers in science, and there are few senior women professors (Moen, 1989). This suggests that there are "barriers to entry" into the scientific workplace and that research should focus upon the organizational as well as the individual level of analysis.

Toward this end, women's experience as faculty members and graduate students was studied in four disciplines (chemistry, physics, computer science, and electrical engineering) at two research universities, one private and one public. We collected quantitative data from academic records and conducted focused interviews with female and male faculty members, graduate students, and administrators. In addition, a department of molecular biology with a critical mass of women faculty was studied at a third university for a total of nine departments. Our findings are reported here with special reference to computer science.

Male and Female Models of Doing Science

Women faculty members generally felt that they had a precarious toehold in academia, even when they were quite successful. There was a strong, although not universal, feeling of exclusion from informal social relationships and reports of differential treatment of junior male and female faculty by senior male faculty, especially regarding invitations to participate in joint research grants. At Eastern Private Research University, two women had resigned their positions to take appointments at teaching colleges, where they felt that they would be better accepted. The total number of women faculty in these departments was so small even two women constitute a significant proportion of the total number. Some recent women Ph.D.s accepted positions in industry, believing that they could more easily combine family and career in this environment.

In academia, women are typically expected to fit a "male" model of the scientific role by severely limiting other roles and devoting virtually all their time to the worksite. A relatively few women are willing to adapt to the male model of academic science, involving total devotion to work, at least until tenure. Others attempt to define a women's academic model, balancing work and non-work roles, but many drop out, unable to obtain acceptance from a resistant system. Funding constraints exacerbate women's unstable positions as professors. Departments, fearful of productivity losses, grow less willing to tolerate deviation from the traditional model. Even at Western Public Research University, where women in the molecular biology department had gained fullest acceptance as professors, there was concern that funding pressures would disrupt the department's low-key egalitarian culture.

Women who attempt to define an alternative scientific role balance research with other roles and limit their time at the work site. Male faculty members often look upon their research group as a "social club" as well as a workplace, spending time around the lab in non-work activities. By contrast, female faculty who attempt to develop a significant private sphere in their lives strictly limit time in the workplace to professional activities. They are sometimes felt to be not as available to their students as their male colleagues, but are also respected, especially by women students, for their serious commitment to both family and work. These women encounter structural obstacles such as severe limitations on arranging part-time appointments during pregnancy or to undertake child rearing responsibilities. Full leave is typically the choice offered, but that option cuts women off from scientific work.

Other women emulate the male model and, given existing conditions, they are usually the most successful female academics. Most women graduate students seek and are seldom able to find what they call relevant role models: women faculty members who are successfully pursuing scientific careers in tandem with family responsibilities. However, since many women are unwilling to follow the male model and unable to successfully define an alternative scientific role, they either drop out of Ph.D. programs or, if they complete the degree, seek careers in industry or in teaching colleges. Thus, women Ph.D.s frequently sought positions in industry, believing that

there they could more easily combine family and career. Men in some specialty areas are resistant to participation by women. On the other hand, male faculty members whose wives are employed and face problems similar to that of female scientists, are the most aware of and sensitive to women's issues. This phenomenon was especially prevalent at Eastern Private Research University, where the faculty tended to be younger, suggesting that a generational change in attitudes is underway.

The Sexual Separation of Scientists

Labelling science areas as peculiarly male or female leads to avoiding areas of study by one sex or the other. At Eastern Private Research University, some specialty areas are defacto off limits to women (e.g., computer science theory and particle physics), while others are thought by some male faculty to be especially suited to women due to association with traditional sex and work roles (e.g., organic chemistry's close relationship to the biological realm, natural language, and women's traditional expressive role, and typing skills in software). Other areas did not seem to exhibit strong sex typing. Women graduate students felt that astrophysics was freely open to women's participation. At Eastern Public Research University, where the focus of the computer science department was on applications, a female faculty member who concentrated on theory was seen as being marginal to the department. Thus, the particular specialty focused upon for positive or negative evaluation makes little difference in itself. In both computer science departments, women were defined as peripheral to the department's core.

Role Models for Women Graduate Students

Most women graduate students made a sharp distinction between women faculty whom they viewed as relevant and those they viewed as irrelevant as role models. Women faculty who were perceived to be emulating an aggressive male scientist role, attempting to become one of the boys, were not generally viewed as viable models. On the other hand, a woman faculty member who was successfully balancing career and family was seen as a model, even though she was somewhat less available due to time constraints. Of course, this finding does not hold for those very few graduate women who excluded other interests in favor of their career.

The absence of viable female role models in most of the departments studied creates anxiety among women graduate students and is believed by them to contribute to the rate of attrition. The involvement of industrial scientists in the Ph.D. training program in one department, electrical engineering, made available a substitute source of successful relevant role models, namely, women industrial scientists. Men can also serve as role models for women, but the presence of successful women balancing career and family provides a significant impetus to women graduate students who are considering dropping out or reducing their career goals to an M.S. level.

Male faculty members and female graduate students are often at cross purposes in their expectations of each other. American women graduate students strongly felt

the need for a supportive advisor willing to teach the strategies needed to compete and to bolster self-confidence. In seeking such encouragement, women graduate students are presumed by male faculty to want explicit direction in the conduct of research (i.e., to be told what to do and how to do it), whereas women graduate students report that what they want is strategic guidance on how to succeed in the profession.

At Eastern Private Research University, 22% of the female students in the four departments, as compared to 4% of the male students, have female faculty advisors. While the proportion of female and male students entering subfields where female faculty advisors are available is fairly similar (32% and 24%, respectively), the proportion actually signing up with those female professors differs by a factor of four (68% to 17%). Women graduate students seek out women faculty members as advisors in hopes of finding a sympathetic mentor, while male graduate students sign up with a woman only if she has achieved a distinguished position in the field. Female student informants in three departments (physics, chemistry, and computer science) reported both overt and subtle discrimination toward women, with acute consequences to their self confidence, ability to perform, and the possibility of career advancement. In electrical engineering, graduate students typically undertook research in industry where female graduate students were often able to find women mentors.

Women who are viewed as less than totally committed to science will not be taken on as advisees by some male professors. This lack of commitment is operationalized in terms of marriage and child rearing, which are believed to be too distracting to allow full attention to science. Pregnancy is discouraged, and graduate women who have children are encouraged to take leaves of absence that tend to become permanent withdrawals. This phenomenon was found in computer science and the expectation of it creates anxiety, and possibly an increased attrition rate, in chemistry and physics.

At Eastern Private Research University, women graduate students had an attrition rate that was almost double the rate for men. Prior socialization had diminished American women's level of self confidence before entry into graduate school. Women in physics, chemistry, and computer science reported that their graduate school experience further eroded their level of self confidence. On the other hand, at Eastern Public Research University, where the absolute number of female graduate students in the computer science department was extremely small (4 out of 60 or 8.3%), there was no significant difference in the dropout rates, but women's progress to the degree appeared to be slower. There was only one American woman graduate student in the department, a further indicator of paucity of representation but also a clue to why, in their almost complete absence, "women in science" were not considered to be an issue at this university.

The departments under study are considered among the best in Eastern Private Research University by the Affirmative Action Office. Complaints were almost never made about these departments, and in a rare sexual harassment case, the department responded promptly and accepted advice on how to deal with the issue. Scientists were viewed as more willing to focus on the quality of an individual's work than their status.

in contrast to humanities and social science departments, which were viewed as far more problematic. Nevertheless, it is in the humanities and social science departments that women have tended to form organized support groups. The computer science department at Eastern Private Research University, where women communicated about issues of mutual concern through e-mail, was close to having such a support system. Nevertheless, when a woman raised an issue of sexist male faculty behavior over the net, she quickly backed down and did not make an outside complaint once the instance became known in the department, and she became aware that her complaint was viewed negatively by the male faculty. Thus, we can hypothesize that without a strong internal support system, complaints are less likely to be made to external agencies. In this instance, the complaint reached at least the level of group awareness because of the existence of a communication network among women.

Despite a formal, and even at times a strongly stated, commitment to non-discriminatory treatment of women, discrimination was manifested informally through invisibility, isolation, and sexualization. Typical instances reported were: visitors to a laboratory being introduced to male students but not to females; a male faculty member paying excessive attention to the comments of male students in group meetings; and the initiation by a female graduate student of a friendly collegial work relationship with a male graduate student being misinterpreted as an invitation to an intimate social relationship. Differential attention to women students was felt to promote performance stress, while exclusion from informal relations was strongly believed to be a career handicap. Even where covert sexism does not lead to women students dropping out, it still reduces the quality of their graduate experience, even for women who are successful in formal terms.

Policy Implications

Our study focuses on women who have successfully made it through the pipeline, past obstacles at early stages in the life course that deter larger numbers of women from scientific careers. These graduate students and professors, after successfully negotiating the numerous barriers to entry that exclude so many other women, often pursue less demanding careers than their male peers. These are not women lost to science. Rather they are women who are excluded from positions in the top academic departments in their field. Many pursue research careers in industry. Others have taken appointments down the academic ladder. Whether these scientists are excluded from high-level academic careers through discrimination, by academic departments unwilling to accept women as equals, or by choice, through their unwillingness to conform to an academic system that makes little accommodation for non-work roles and obligations, the result is the same. The implication of this finding is that there does not exist an untapped pool of women whom their advisors, usually male, agree are the equals of men who are pursuing careers at the highest academic levels.

However, there is a pool of women Ph.D.s working in industry and lower on the academic ladder whom their advisors, usually men, agree are the equal of their male

peers who are pursuing research careers at the highest academic levels. Thus, if lines were made available through university policy and/or national programs, qualified women could be recruited to create a critical mass of at least three senior women in each leading computer science department. This would provide the range of female role models necessary to bring forth a significantly larger next generation of women computer scientists.

The process by which women enter departments appears to be autoregressive: the number of women in a department is a function of the women already available to offer social and intellectual support. We hypothesize that the development of a critical mass of women faculty and graduate students in a department will result in a reduction of structural barriers, positively affect the culture of a department, and either restrict the expression of, or change, negative male attitudes, thereby increasing the success rate of women faculty and graduate students in achieving tenure and degrees. This transition has occurred in the molecular biology department that we studied. Before the transition, the departmental rule of "hiring the best persons available" brought forth only men. After the transition, half the new hires were male and half were female. The cause of the transition itself appeared to be a combination of local conditions and a competitive strategy of a department on the make. A crucial event was a change of heart of a departmental chair toward a woman faculty member about to be considered for tenure, and the issuing of a call to other male faculty members to reconsider their negative attitudes toward women. There was also an astute recognition that since other departments were less than willing to hire women, a department that did could attract top people in the field and eventually, as their work was recognized, help itself move up in the disciplinary pecking order.

The Contradiction between the Biological Clock and the Tenure Clock

There is an incompatibility between the seven-year race for tenure and the biological clock for child bearing, with obvious negative consequences for women's participation in high-powered academic science. If the objective is to significantly increase the number of women pursuing high-level scientific careers, institutional accommodations will have to be made for women who wish to combine family with career. Achieving equality is not just a matter of opening up opportunities, but of changing the structure of the academic system. Women who wish to pursue traditional female roles along with a scientific career must be accommodated by allowing a longer time span before the tenure decision. This accommodation had been promised to one faculty member in our sample, although in the end it was not allowed.

This is not a call for a "mommy track" with different and lower expectations of achievement and rewards, but a serious effort to accommodate the significant number of women who are not willing to forego family and children prior to tenure. It is unrealistic to expect significant numbers of women to follow the male model. If the goal is to substantially increase the participation of women in high-level academic science, a female model will have to be legitimized. Acceptance of an alternative

career model is crucial to placing more women in faculty slots in the short term, which in turn is necessary to insure relevant role models for a broader range of female graduate students.

Conflicts of Time

Conflicts of time will have to be accommodated for women faculty members with children. These women are often in the early and most vulnerable stages of their careers. Time conflicts are currently accommodated for faculty members, typically men, who found firms or centers. However, these time conflicts usually occur after tenure, while women's time conflicts involving family responsibilities tend to occur earlier in their career trajectory, prior to tenure, placing them at risk. While time conflicts at later career stages may affect colleagues' views of a department member, they seldom, if ever, have deleterious career consequences. Simply put, women are more vulnerable than men prior to tenure.

Overcoming Geographic Immobility

Another issue is the limited geographic mobility of many women that restricts their choice of both graduate school and job. Many women select their graduate school based on what is available in a region, and choose a job with similar considerations. In many instances second-rate research universities attract higher quality candidates than they might otherwise, due to women's geographic restrictions. In the short term, one way of addressing this problem would be to relax formal and/or informal prohibitions against hiring one's own graduates. The highest achieving woman scientist in our sample was hired by her graduate department after a stint at a local college. This practice is especially significant for women who are geographically immobile in a region with few or even only one research university.

Conclusions

Women who have overcome the cumulative disadvantages that deter most women from undertaking graduate work in the sciences, nevertheless suffer distinct disadvantages at the graduate and junior faculty stages that significantly reduce the entry of women into research careers in academic science. Since these advantages are encountered after the hurdles of cumulative disadvantage have been passed, we call them marginal disadvantages. They affect those women who have entered scientific careers in spite of the barriers that have severely reduced the ranks of women scientists. While the causes of cumulative disadvantage are largely beyond the control of academic departments, the causes of disadvantage at the graduate student and junior faculty levels such as advisement, role modeling, and hiring practices, are part of the academic enterprise, and departments can influence how they take place. In professional associations, committees on the status of women can function as mini-social movements to get the associations to pressure departments to take action. The National Science Foundation plays a role in offering special grants competitions for women,

making up, in part, for the deficit in socialization of women into the grants system during graduate training. However, until affirmative action pressures from the federal government are revived, it is unlikely that most departments will define the paucity of women in science as a serious problem.

References

- Cole, J. R. & Zuckerman, H. (1987). Marriage and motherhood and research performance in science. *Scientific American*, 256, pp. 119-125.
- Etzkowitz, H., Kemelgor, C., & Neuschatz, M. (1989). *The final disadvantage: Barriers to the recruitment of women in science and engineering*. A report to the National Science Foundation. Technical report, Center for Science and Technology Policy, Rensselaer Polytechnic Institute.
- Long, S. (forthcoming). The origins of sex differences in science.
- Moen, P. (1988). *Women as a human resource*. National Science Foundation.
- Mulkay, L. (1988). *Universalism in science: An empirical investigation of attitudes toward women in science*. American Sociological Association Annual Meetings.
- Widnall, S. E. (1988). Voices from the pipeline. *AAAS Presidential Lecture 241*: 1740-1745.

About the Authors

Henry Etzkowitz is currently with the sociology department at the State University of New York at Purchase and with the computer science department at Columbia University. He earned a B.A. at the University of Chicago, and a Ph.D. at the New School for Social Research.

Recent publications include:

Etzkowitz, H. (forthcoming). Barriers to women in academic science and engineering. In Pearson, W. & Fechter, I. (eds.) *Human Resources for Science*, Baltimore: Johns Hopkins University Press.

Mr. Etzkowitz is the Chair for the Section on Science, Knowledge and Technology of the American Sociological Association, and is an editor, with Ronald Glassman, of *The Renaissance of Sociological Theory*.

Carol Kemelgor is currently with the New York University School of Social Work. She earned a B.A. at the State University of New York at Purchase, and an M.S.W. at New York University.

She recently coauthored a chapter with Henry Etzkowitz in the forthcoming *Women and Minorities in Science* ed. Willie Pearson, Wake Forest Press.

Her research interests are in the area of the organization of research groups and roles of women in science. In addition, she has been involved in exploring the organization and structure of research centers in relation to small science.

Michael Neuschatz is currently with the American Institute of Physics. He earned a B.A. and a Ph.D. both at the University of Colorado, Boulder.

Recent publications include:

Neuschatz, M. (1989, August). Reaching the critical mass in high school physics. *Physics Today*, 42 (8), 30-36.

Neuschatz, M. (1988). *Physics in the high schools*. New York: American Institute of Physics.

Neuschatz, M. (1986). *The Golden Sword: The Coming of Capitalism to the Colorado Mining Frontier*. Westport, CT: Greenwood Press.

His research interests include: socio-economic development research in developing countries; international science education research; and gender and racial/ethnic group differences in science background.

Brian Uzzi is currently working on a Ph.D. in sociology at the State University of New York at Stony Brook. He earned a B.A. at Hofstra University, and an M.S.I.A. at Carnegie-Mellon University.

Recent publications include:

Uzzi, B., Kilmann, R.H. & Shellerman, J. (1990). Integrating different approaches for achieving competitiveness. In Kilmann (Ed.), *Making Organizations Competitive*.

Uzzi, B., Moorman, C. & Russo-Frank, K. (1990). A framework for the conceptualization, design, and strategic management of planned change systems. In *Knowledge and Society*.

His research interests focus on the causes and consequences of organizational decline and deindustrialization, organizational relations and alliances, and new organizational forms.

IV. GENDER EQUITY RESOURCES

Gender Equity—A Partial List of Resources

Cindy Meyer Hanchey
Oklahoma Baptist University

Articles, Books, and Brochures

- Brecher, D. (1986). *The woman's computer literacy handbook*. New American Library.
- Clarke, V. A. & Chambers, S. M. (1989). Gender-based factors in computing enrollments and achievement: Evidence from a study of tertiary students. *Journal of Educational Computing Research*, 5 (4), pp. 409-429.
- Damarin, S. K. (1989, April). Rethinking equity: An imperative for educational computing. *The Computing Teacher*, 16 (7), pp. 16-18, 55.
- Do your female students say 'No, thanks' to the computer?* Women's Action Alliance and Apple Computer Company, 1987. (See Women's Action Alliance for ordering information)
- Does your daughter say 'No, thanks' to the computer?* Women's Action Alliance and Apple Computer Company, 1989. (See Women's Action Alliance for ordering information)
- Flodin, K. C. (1988). Female firsts. *Woman's Day*, March 29, p. 26.
- Fox, L. H., Brody, L., and Tobin, D. (1980). (Eds.) *Women and the mathematical mystique*. The John Hopkins University Press.
- Frazier, N. & Sadker, M. (1973). *Sexism in school and society*. Harper and Row.
- Frenkel, K. A. (1990, November). Women and computing. *Communications of the ACM*, pp. 34-46.
- Freundlich, N. (1989) Making science more seductive to women on campus. *Business Week*, August 28.
- Hunsaker, J. & Hunsaker, P. (1986) *Strategies and skills for managerial women*. South-Western Publishing Co.
- Kantrowitz, B. et al. (1990, October 15) Can the boys be saved? *Newsweek*; p. 67.
- Keith, S. Z. & Keith, P., (Eds.) (1989, November). *Proceedings of The National Conference on Women in Mathematics and The Sciences*. St. Cloud University, St. Cloud, MN 56301.
- Kiesler, S., Sproull, L., & Eccles, J. S. (1983, March). Second-class citizens? *Psychology Today*, pp. 40-48.
- Kiesler, S., Sproull, L., & Eccles, J. S. (1985). Poolhalls, chips and war games: Women in the culture of computing. *Psychology of Women Quarterly*, 9 (4), pp. 451-463.
- Klein, S. S., (ed.) (1985). *Handbook for achieving sex equity through education*. The Johns Hopkins University Press (701 West 40th Street, Suite 275; Baltimore, MD 21211).
- Kolata, G. (1984, January). Equal time for women. *Discover*, pp. 24-27.
- Leveson, N. (1990, October) NSF programs for women, minorities, and the disabled. *Computing Research News*, pp. 11, 13.

- Linn, M. C. & Hyde, J. S. (1989, November). Gender, mathematics, and science. *Educational Researcher*, 18, pp. 17-19, 22-27.
- Lockheed, M. E. & Frakt, S. B. (1984, April). Sex equity: Increasing girls' use of computers. *The Computing Teacher*, pp. 231-234.
- Lytle, V. (1990, March). From Marie Curie....to Sally Ride....to.... *NEA Today*, pp. 4-5.
- Making the case for math*. A special report on elementary mathematics in the 1990s from D. C. Heath and Company. (1-800-235-3565)
- Marcoulides, G. A. (1988). The relationship between computer anxiety and computer achievement. *Journal of Educational Computing Research*, 4(2), pp. 151-158.
- Math for the 90's: An action guide for instructional leaders*. from D. C. Heath and Company. (1-800-235-3565).
- Menzin, M. & Goldman, R. (1987). *Careers in mathematics*. Association for Women in Mathematics, (See Association for Women in Mathematics for ordering information).
- McCarthy, R., (1989, October). Behind the scenes at Bank Street College. *Electronic Learning*, pp. 30-34.
- Not just for nerds. (April 9, 1990). *Newsweek*, pp. 52-54.
- Ogilvie, M. B. (1986). *Women in science, antiquity through the Nineteenth Century: A biographical dictionary*. MIT Press.
- Ogozalek, V. Z. (1989, June). A comparison of male and female computer science students' attitudes toward computers. *SIGCSE Bulletin*, 21 (2), pp. 8-14.
- Pearl, A., Pollack, M. E., Riskin, E., Wolf, E., & Wu, A. (1990, November). Becoming a computer scientist. *Communications of the ACM*, pp. 47-57.
- Perl, T. H. & Manning, J. M. *Women, numbers and dreams*. National Women's History Project. (See National Women's History Project for ordering information.)
- Powell, G. N. (c1988). *Women & men in management*. SAGE Publications (The Publishers of Professional Social Science).
- R, for learning. (April 9, 1990). *Newsweek*, pp. 55-64.
- Sadker, D. & Sadker, M. (1982). *Sex equity handbook for schools*. (2nd ed.) Longman Inc., reprinted by the Carnegie Corporation. (See Women Educators for ordering information.)
- Sanders, J. (1990, March). Developing software for gender equity: A review of breaking the barriers. *The Computing Teacher*, pp. 54-55.
- Sanders, J. & Stone, A. (1986). *Equal play: The neuter computer: Computers for girls and boys*. Neal-Schuman Publishers. (See Women's Action Alliance for ordering information)
- Shapiro, L. (1990, May 28). Guns and dolls. *Newsweek*, pp. 56-65.
- Stallings, S. (1984, April 3). Computer equality for women. *PC Magazine*, pp. 71-73.
- Stern, M., (ed.). *Changing sexist practices in the classroom*. Women's Rights Committee, American Federation of Teachers, AFL-CIO, publication #600, nd.
- Stone, A. (1986, November). Action for equity column, adapted from an address to The National Education Technology Leadership Conference, *The Computing Teacher*, pp. 54-55.

- Tobias, S. (1990). *They're not dumb, they're different*. Research Corporation, 6840 East Broadway Blvd., Tucson, AZ 85710-2815.
- Wallace, J. M. (1986, Winter). Nurturing an 'I can' attitude in mathematics. *Equity and Choice*, 11 (2), pp. 35-40.
- Women in science and technology: Careers for today and tomorrow*. The American College Testing Program, (ACT Publications; Box 168; Iowa City, Iowa 52240), 1976.

Modeling Equitable Behavior in the Classroom

(12 technical assistance and training modules).

Desegregation Assistance Center—South Central Collaborative, Intercultural Development Research Association; 5835 Callaghan Rd., Suite 350; San Antonio, TX 78228 (\$7.50 each or \$75.00 for the entire series)

Technical Assistance Modules:

- Federal Statutes and Directives Regarding National Origin Students
- Federal Statutes and Directives Regarding Title IX Compliance
- Civil Rights Compliance: An Update

Training Modules:

- I. First and Second Language Acquisition Processes
- II. Integrating the ESL Student into the Content Area Classroom
- III. Recognizing Cultural Differences in the Classroom
- IV. Sex Stereotyping and Bias: Their Origin and Effects
- V. Modeling Equitable Behavior in the Classroom
- VI. Avoiding Sex Bias in Counseling
- VII. Equity in Counseling and Advising Students: Keeping Options Open
- VIII. Interpersonal Communications: A Human Relations Practicum
- IX. It's a Matter of Race: Race Relations in the Desegregated Setting

National Science Foundation

(202-357-3619 for NSF Forms & Publications) publishes the following:

Achieving full participation of women in science and engineering. (1989, October 25).

Leveson, N. (1989, December). *Women in computer science*.

Profiles—Computer sciences: Human resources and funding. (1988, November). (NSF 88-324).

Women and minorities in science and engineering. (1990, January). (NSF 90-301).

Teachers College Press; Teachers College; Columbia University; New York, NY 10027 publishes the following:

Baroody, A. J. (1987) *Children's mathematical thinking. A developmental framework for preschool, primary, and special education teachers*.

Bowers, C. A. (1988). *The cultural dimensions of educational computing. Understanding the non-neutrality of technology*.

- Davis, B. G. & Humphreys, S. (1985). *Evaluating intervention programs, Applications from women's programs in math and science.*
- Hall, K. A., (Ed.) *Computers and education series.*
- Fennema, E. & Leder, G., (Eds.) (1990). *Mathematics and gender.*
- Riordan, C. (1990). *Girls and boys in school, Together or separate?*
- Sprung, B., (Ed.) (1978). *Perspectives on non-sexist early childhood education.*

Organizations

- Agency Instructional Technology (AIT); Box A, 1111 West 17th Street; Bloomington, IN 47401 (Women in Science videotape series)
- American Association of University Women; 2401 Virginia Avenue, NW; Washington, DC 20037 (free resource list of publications)
- American Institutes for Research; PO Box 1113; Palo Alto, CA 94302 ("IDEAS for Equity in Computer Learning" available for \$15)
- American Statistical Association; Committee on Women in Statistics; 806 15th Street, NW; Washington, DC 20005 (brochures, local contacts)
- Association for Women in Computing (AWC); Ms. Vicki Birch, CDP; Independent Members Representative; 9417 Shouse Dr.; Vienna, VA 22182 (newsletter, local chapters)
- Association for Women in Mathematics; Box 178; Wellesley College; Wellesley, MA 02181 (booklets, bibliographies, speakers' bureau, career brochures)
- Association for Women in Science; 1522 K Street, NW, Suite 820; Washington, DC 20005 (newsletter, legislative updates, grant information, bibliographies)
- Association of American Colleges; Project on the Status and Education of Women; 1818 R Street, NW; Washington, DC 20009 (newsletter and other publications; Bernice Sandler and Roberta Hall, "Campus Climate" reports, 1982 and 1986)
- Curriculum Publications Clearinghouse; Western Illinois University; Horrabin Hall 46; Macomb, IL 61455 (Building Fairness/Sex Equity materials and videos)
- Didatech Software, Ltd.; Burnaby, British Columbia, Canada; 604-299-4435 (*Fay: That Math Woman, Fay: The Word Hunter, Fay's Word Rally*—software primarily for early grades, remediation and special education)
- Duke University Talent Identification Program (TIP); Box 40077; Durham, NC 27706-0077 (received grant from Burrough's Welcome Fund to encourage young women and minorities to explore careers in science through Duke's Summer Residential Program)
- EQUALS; Lawrence Hall of Science; University of California; Berkeley, CA 94720
- FairTest; PO Box 1272; Cambridge, MA 02238
- Girls Incorporated; 30 East 33rd Street; New York, NY 10016 (Operation SMART—a program to encourage every girl in Science, Math and Relevant Technology)
- GrayMill; Rt. 1, Box 45; Earlham, Iowa 50072 (independent educational consulting agency; publications including *Handbook for Achieving Sex Equity Through Education* available for ordering)

- Hampshire College; Amherst, MA ("Day in the Lab" program for junior high girls)
- Hartley Courseware, Inc.; Box 419; Dimondale, MI 48821 ("Women in History" software)
- Hawkhill Associates, Inc.; 125 East Gilman Street; Madison, WI 53703 ("Women in Science" videos)
- Math/Science Network; 2727 College Avenue; Berkeley, CA 94705 (*Broadcast* quarterly newsletter, "Expanding Your Horizons in Science and Mathematics" conferences, other publications and videos)
- National Council of Teachers of Mathematics; 1906 Association Drive; Reston, VA 22091 (videotape and workshop intervention program)
- The National Women's Hall of Fame; 76 Fall Street; Seneca Falls, NY 13148
- National PTA; 700 N. Rush Street; Chicago, IL 60611 ("Math Matters" kit and brochure)
- National Science Foundation Young Scholars Program; Washington, DC 20550 (202 357-3619 for NSF Forms & Publications) (program designed for students entering grades 8-12 used to encourage careers in science, mathematics, engineering, and technology; some with emphasis on recruitment of women and minorities)
- National Women's History Project; 7738 Bell Road; Windsor, CA 95492-8518 (multicultural resources including books, videos, kits, and posters)
- National Science Teachers Association; 1742 Connecticut Avenue, NW; Washington, DC 20009 ("Science Career Exploration for Women" and "Women Scientists Roster")
- OPTIONS; The LEADERSHIP TEXAS Math/Science Project for Girls; Leadership Texas Alumnae Association; Box 50224; Austin, TX 78763 (video, anthology, bibliography)
- Project on Equal Education Rights (PEER); 99 Hudson Street, 12th Floor; New York, NY 10013 (Computer Action Equity Kits, other materials)
- Project SITE (Successful Inservice Through Turnkey Education); Staten Island, NY (project to encourage development of higher-level thinking skills through the use of manipulatives for upper elementary and middle school classes)
- Rhiannon Software; Addison-Wesley Publishers; One Jacob Way; Reading, MA 01867 (*Cave Girl Clair, Jenny's Journey*, software for girls)
- Sex Desegregation Assistance Center of the Southwest; Stephen F. Austin State University; Box 13010-A SFA Station; Nacogdoches, TX 75962
- U.S. Department of Education; Fund for the Improvement and Reform of Schools and Teaching; 555 New Jersey Ave., NW, Room 522; Washington, DC 20208 (funds for improving mathematics and science instruction in elementary and secondary schools)
- U.S. Department of Labor; Office of the Secretary, Women's Bureau; 200 Constitution Avenue, NW; Washington, DC 20210-9990 (Facts on Working Women)
- Wings for Learning, A Sunburst Company; PO Box 660002; Scotts Valley, CA 95067-0002 (science and math programs)

Women and Mathematics Education (WME), c/o SummerMath; Mt. Holyoke College; 302 Shattuck Hall; South Hadley, MA 01075

Women Educators; Wisconsin Department of Public Instruction; PO Box 7841; Madison, WI 53707

Women's Action Alliance; The Sex Equity in Education Program; 370 Lexington Avenue; New York, NY 10017 *Equal Play; the Neuter Computer: Computers for Girls and Boys*, \$24.95; "Do/Does Your...Say 'No, Thanks,'" (single copy free, quantity discounts available)

Women's Educational Equity Act (WEEA) Publishing Center, Education Development Center; 55 Chapel Street, Suite 200; Newton, MA 02160 (gender-fair resources)

Women's Computer Literacy Center; PO Box 68; Jenner, CA 95450

About the Author

Cindy Meyer Hanchey is currently at Oklahoma Baptist University. She earned her B.S. and her M.B.A. both from Louisiana State University, and is a Certified Data Educator.

Recent publications include:

Hanchey, C.M. (1990, Summer). Using a spreadsheet to create matching-term exams. *Interface*.

Hanchey, C.M. (1988). *Using electric desk—A lab manual*. Wm. C. Brown.

She was recently a panelist and referee for the A.C.M. Special Interest Group on Computer Science Education at the National Educational Computing Conference, and for the Association for Computer Educators. Her interests are computer science education, curriculum and course development, and gifted education.

V. APPENDIX

Epistemological Pluralism: Styles and Voices Within the Computer Culture

Sherry Turkle

Massachusetts Institute of Technology

Seymour Papert

Massachusetts Institute of Technology

1. Epistemological Pluralism

The prevailing image of the computer represents it as a logical machine and computer programming as a technical, mathematical activity. Both the popular and technical culture have constructed computation as the ultimate embodiment of the abstract and formal. Yet the computer's intellectual personality has another side: our research finds diversity in the practice of computing that is denied by its social construction. When we looked closely at programmers in action we saw formal and abstract approaches; but we also saw highly successful programmers in relationships with their material that are more reminiscent of a painter than a logician. They use concrete and personal approaches to knowledge that are far from the cultural stereotypes of formal mathematics.¹

The diversity of approaches to programming suggests that equal access to even the most basic elements of computation requires accepting the validity of multiple ways of knowing and thinking, an epistemological pluralism. Here we use the word epistemology in a sense closer to Piaget's than to the philosopher's.² In the traditional usage, the goal of epistemology is to inquire into the nature of knowledge and the conditions of its validity; and only one form of knowledge, the propositional, is taken to be valid.³ The step taken by Piaget in his definition of "epistemologie genetique"

¹ Research reports that emphasize approach to programming or programming style in the sense we are using it here include Seymour Papert, Andrea di Sessa, Sylvia Weir, and Daniel Watt, "Final Report of the Brookline Logo Project," Logo Memos 53 and 54, Massachusetts Institute of Technology, Cambridge, MA, 1979; Sherry Turkle, "Computer as Rorschach," *Society* 17 (December 1980): 15-22; Sherry Turkle, *The Second Self: Computers and The Human Spirit* (New York: Simon and Schuster, 1984), especially Chapter 3; Sylvia Weir, *Cultivating Minds: A Logo Casebook* (New York: Harper and Row, 1987); Sherry Turkle, Donald Schon, Brenda Nielsen, M. Stella Orsini, and Wim Overmeer, "Project Athena at MIT," (unpublished ms., May 1988); Lise Motherwell, "Gender and Style Differences in a Logo-Based Environment" (Ph.D. diss., Massachusetts Institute of Technology, January 1988); Idit Harel, "Software Design for Learning: Children's Construction of Meaning for Fractions and Logo Programming," (Ph.D. diss., Massachusetts Institute of Technology, June 1988).

² Piaget's use of the term epistemology is pervasive in his writing. See, in particular, *Introduction a Epistemologie Genetique* vol. 1-3 (Paris: Presses Universitaires de France, 1950). Alvin Goldman discusses the modern redefinition of the field of epistemology as something as close to psychology and sociology as to philosophy in *Epistemology and Cognition* (Cambridge, MA: Harvard University Press, 1986).

© 1990, The University of Chicago Press. Reprinted with permission from *SIGNS Magazine* 16: 1 (Autumn, 1990) pp. 128-157. Published by The University of Chicago Press.

was to eschew inquiry into the "true" nature of knowledge in favor of a comparative study of the diverse nature of different kinds of knowledge, in his case the kinds encountered in children of different ages. We differ from Piaget on an important point, however. Where he saw diverse forms of knowledge in terms of stages to a finite end point of formal reason, we see different approaches to knowledge as styles, each equally valid on its own terms.

The barriers to acknowledging such pluralism are great, historically rooted in domains that go far beyond computation. The formal, propositional way of knowing, has been recognized traditionally as a standard, canonical style. Indeed, philosophical epistemology has generally taken it as synonymous with knowledge. Where concrete approaches to knowledge have been recognized at all, it has most often been as inferior ways of knowing, the kinds of knowing adopted by necessity by those who have not yet mastered the canonical style. Thus Jean Piaget recognizes in young children ways of thinking that do not conform to the canon but which are too coherent and efficacious to be branded simply as "wrong." He casts children's concrete thinking as a stage in a progression to a formal style.⁴ Similarly, Claude Levi-Strauss recognizes "bricolage," a "science of the concrete," but relegates it to primitive societies, a manifestation of the "savage mind."⁵

More recently, concrete ways of thinking have been recognized in contexts that are not easily dismissed as inferior. Ethnographers of science studying the daily life of the laboratory have found that scientific discoveries are made in a concrete, ad hoc fashion, and only later recast into canonically acceptable formalisms.⁶ Scientific biography reveals that Nobel laureates relate to their materials in the concrete and tactile style of Levi-Strauss' bricoleurs.⁷ Psychologists investigating adults' mathematical thinking find that they use an effective and down-to-earth style very different from the abstract and formal math they were taught at school.⁸ Feminist scholars have documented the power of concrete, contextual reasoning in a wide range of domains.⁹

³ For a critical and polemical account of this history, see Paul M. Churchland, *A Neurocomputational Perspective: the Nature of Mind and the Structure of Science* (Cambridge, MA: The MIT Press, 1989).

⁴ See for example, Jean Piaget and Barbel Inhelder, *The Growth of Logical Thinking from Childhood to Adolescence* (New York: Basic Books, 1958).

⁵ Claude Levi-Strauss, *The Savage Mind* (Chicago: University of Chicago Press, 1968).

⁶ A sample of relevant studies in scientific ethnography is provided by Karin Knorr-Cetina and Michael Mulkay, eds., *Science Observed: Perspectives on the Social Studies of Science* (London: Sage Publications, 1983). See also Karin Knorr-Cetina, *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science* (Pergamon: Oxford, 1981); Bruno Latour and Stephen Woolgar, *Laboratory Life: The Social Construction of Scientific Facts* (Beverly Hills CA: Sage, 1979); Sharon Traweek, *Beamtimes and Lifetimes: The World of High Energy Physicists* (Cambridge, MA: Harvard University Press, 1989).

⁷ Evelyn Fox Keller, *A Feeling for the Organism: The Life and Work of Barbara McClintock* (San Francisco: W.H. Freeman, 1983).

With such contributions has come a growing convergence of intellectual commitments to a revaluation of the concrete; but in general, the ethnographers, psychologists, and feminist scholars who have contributed to this revaluation have not seen computation as relevant to their concerns. Here we present evidence which points towards the possibility of new intellectual alliances.

In our research on programming styles, the computer has emerged as an important actor in the revaluation of the concrete, a privileged medium for the growth of alternative voices in dealing with the world of formal systems. The conventional route into formal systems, through the manipulation of abstract symbols, closes doors that the computer can open. The computer, with its graphics, its sounds, its text and animation, can provide a port of entry for people whose chief ways of relating to the world are through movement, intuition, and visual impression. At the heart of the new possibilities for the appropriation of formal systems is the computational object, on the border between an abstract idea and a concrete physical object. In the simplest case, a computational object such as an icon moving on a computer screen can be defined by the most formal of rules and is thus a mathematical construct, but at the same time it is visible, almost tangible, and allows a sense of direct manipulation that only the cultured mathematician can feel in traditional formal systems.¹⁰ The computer has a theoretical vocation: it can make the abstract concrete; it can bring formality down-to-earth.

¹⁰ A sample of studies on everyday thinking is contained in Barbara Rogoff and Jean Lave, eds., *Everyday Cognition: Its Development in Social Context* (Cambridge, MA: Harvard University Press, 1984). Also see, Jean Lave, *Cognition in Practice: Mind, Mathematics and Culture in Everyday Life* (Cambridge: Cambridge University Press, 1988).

⁹ See, for example, Mary Field Belenky, Blythe McVicker Clinchy, Nancy Rule Goldberger, and Jill Mattuck Tarule, *Women's Ways of Knowing: The Development of Self, Voice, and Mind* (New York: Basic Books, 1986). Edited collections that focus on approaches to knowing in science include: Ruth Bleir, ed., *Feminist Approaches to Science* (New York: Pergamon, 1986) and Sandra Harding and Merrill B. Hintikka, eds., *Discovering Reality: Feminist Perspectives on Epistemology, Metaphysics, Methodology, and Philosophy of Science* (London: Reidel, 1983). An overview that highlights many of the issues we deal with in this essay is provided by Elizabeth Fee, "Critiques of Modern Science: The Relationship of Feminism to Other Radical Epistemologies" in Bleir, *Feminist Approaches*.

In this essay we situate our position by focusing on two writers, Carol Gilligan and Evelyn Fox Keller. Gilligan, with her emphasis on moral discourse might seem out of place in a discussion of non-canonical approaches to science and technology. But here we argue that key issues in the critique of science are not about scientific reasoning but about reasoning. Juxtaposing moral and computational reasoning helps us make this point. In addition, Gilligan's critical relationship to the theories of Lawrence Kohlberg is analogous to our own critical relationship to Piaget's work. We emphasize Keller because her work underscores as does ours, the importance of relationships with objects in the development of non-canonical styles. Using Gilligan and Keller as a contrasting pair allows us to highlight two different dimensions of what we call the concrete approach to science. See Carol Gilligan, *In A Different Voice: Psychological Theory and Women's Development* (Cambridge: Harvard University Press, 1982); Evelyn Fox Keller, *A Feeling for the Organism: The Life and Work of Barbara McClintock*; Evelyn Fox Keller, *Reflections on Gender and Science* (New Haven: Yale University Press, 1985).

We have studied computers and the cultures that grow up around them in a wide variety of settings ranging from video game arcades to research laboratories of artificial intelligence. In this paper we draw particularly on a long-term line of research on how people enter the culture of programming. Using clinical methods inspired by the Piagetian and psychoanalytic traditions, we built up case studies of children using computers in grade school settings and college students taking a first programming course. We saw many manifestations of the concrete approach, favored in our study by more women than men. We were also able to observe people reacting poignantly to what they felt as a pressure to conform to an officially imposed style.¹¹ Although the computer as an expressive medium supports epistemological pluralism, the computer culture often does not. Our data points to discrimination in the computer culture that is determined not by rules that keep people out but by ways of thinking that make them reluctant to join in. Moreover, the existence of diverse styles of expert programming supports the idea that there can be different but equal voices even where the formal has traditionally appeared as almost definitionally supreme: in mathematics and the sciences.

Evelyn Fox Keller has remarked on the difficulty that people face when they try to understand what it might mean to do science in anything other than the formal and abstract canonical style. Describing such a style in the work of geneticist Barbara McClintock, Keller notes that this is the "less accessible aspect" of a scientist's relationship to nature.¹² In this essay we describe people learning to program who are having experiences with formal systems that are in many ways analogous to those of the bricoleur scientist or mathematician. One way the computer contributes to the revaluation of concrete approaches in the domain of formal systems is by giving more people access to (and an experience of) them.

The computer forces general questions about intellectual style to reveal an everyday face.¹³ Even schoolroom differences in how children program computers

¹⁰ See Philip J. Davis and Reuben Hersh, *The Mathematical Experience* (Boston: Houghton Mifflin, 1981) and Seymour Papert, "The Mathematical Unconscious" in Judith Wechsler, ed., *Aesthetics and Science* (Cambridge, MA: MIT Press, 1980).

¹¹ For grade school children we worked with forty cases. Of the twenty girls in our study, fourteen preferred concrete approaches, of twenty boys there were four who followed this route. In the study of college students taking a first programming course, of the fifteen women, nine were concrete style programmers, of fifteen men, four. Because of our interest in spontaneous approaches we classified as concrete thinkers some students who finally adopted elements of the canonical approach in order to please their teachers. (See for example, the cases of Lisa and Robin, below.) In our research, the male/formal and female/concrete dichotomy was most dramatic in a predominantly white, wealthy private school in the South where traditional patterns of socialization would favor boys learning the ways of control, hierarchy, and distance and girls learning the ways of negotiation and closeness.

¹² Keller, *A Feeling for the Organism*, 198.

¹³ For a fuller discussion of the computer as an evocative and concretizing object see Sherry Turkle, *The Second Self: Computers and the Human Spirit* (New York: Simon and Schuster, 1984).

raise issues that come up in a more abstract form in scholarly debates about scientific objectivity. The computer makes ideas about non-canonical scientific voices more concrete and therefore appropriable because we can relate them not only to the science of the scientists but to our own thinking.

Here we focus on descriptions of a concrete way of knowing; the formal, canonical style is well known and well defended. Yet, our discussion of concrete approaches is implicitly a discussion of formal ones; it contributes to the deconstruction of the canonical style as the only way to think. It also situates it: the supervaluation of the formal approach owes much of its strength within computation to the support it gets in other intellectual domains. Formal thinking, defined as synonymous with logical thinking, has been given a privileged status which can be challenged only by developing a respectful understanding of other styles, where logic is seen as a powerful instrument of thought but not as the "law of thought." In this view, "logic is on tap not on top." As a carrier for pluralistic ideas about approaches to knowledge, the computer may hold the promise of catalyzing change not only within the computer culture but in the culture at large.

2. Personal Appropriation

Consider Lisa, eighteen, a first-year Harvard University student in an introductory programming course. Lisa fears that she will find the course difficult because she is a poet, "good with words not numbers." In high school, she had always scorned teachers who had insisted that mathematics is a language. Yet, now, her first encounter with the computer has made Lisa ready to reconsider this proposition and with it her characterization of herself as someone "bad at math." Lisa starts well, surprised to find herself easily in command of the course material; but as the term progresses she reluctantly decides that she "has to be a different kind of person with the machine." The pressure to do so is not from the computational medium. She says she can no longer resist pressure from her teachers to think in ways that are not her own.

Lisa wants to manipulate computer language the way she works with words as she writes a poem. There, she says, she "feels her way from one word to another," sculpting the whole. When she writes poetry, Lisa experiences language as transparent, she knows where all the elements are at every point in the development of her ideas. She wants her relationship to computer language to be similarly transparent. When she builds large programs she prefers to write her own, smaller, building block procedures even though she could use prepackaged ones from a program library; she resents the opacity of prepackaged programs. Her teachers chide her, insisting that her demand for transparency is making her work more difficult; Lisa perseveres, insisting that this is what it takes for her to feel comfortable with computers.

Two months into the programming course, Lisa's efforts to succeed are no longer directed towards trying to feel comfortable. She has been told that the "right way" to do things is to control a program through planning and black-boxing, the technique that lets you exploit opacity to plan something large without knowing in advance how the details will be managed. Lisa recognizes the value of these techniques—for

someone else. She struggles against using them as the starting points for her learning. Lisa ends up abandoning the fight, doing things "their way," and accepting the inevitable alienation from her work. She calls her efforts to become "another kind of person with the machine" her "not-me strategy," and begins to insist that the computer is "just a tool." "It's nothing much," she says, "just a tool." Lisa's growing sense of alienation does not stem from an inability to cope with programming but from her ability to handle it in a way that comes into conflict with the computer culture she has entered.

A classmate, Robin, is a pianist. Robin explains that she masters her music by perfecting the smallest "little bits of pieces" and then building up. She cannot progress until she understands the details of each small part. Robin is happiest when she uses this tried and true method with the computer, playing with small computational elements as though they were notes or musical phrases. Like Lisa, she is frustrated with using prepackaged programs. She, too, has been told her way is wrong: "I told my teaching fellow I wanted to take it all apart and he laughed at me. He said it was a waste of time, that you should just black box, that you shouldn't confuse yourself with what was going on at that low level."

Lisa and Robin came to the programming course with anxieties about not belonging (fearing that the computer belonged to male hackers who lived in "a world apart") and their experiences in it only served to validate their fears.¹⁴ Although carefully designed and imaginative, the Harvard University course taught that there is only one right way to approach the computer, a way that emphasizes control through structure and planning. There are many virtues to this computational approach (it makes sense when dividing the labor on a large programming project, for instance) but Lisa and Robin have intellectual styles at odds with it. Lisa says she has "turned herself into a different kind of person" in order to perform and Robin says she has learned to "fake it." Although both women got good grades in this programming course, both have had to deny who they are in order to succeed.

Lisa and Robin's experiences make it clear that the computer can be a partner in a great diversity of relationships, that the computer is an expressive medium that different people can make their own in their own way. Yet those who wish to approach the computer in a non-canonical way are discouraged by the dominant computer culture, eloquently expressed in the ideology of the Harvard University course. They are asked to change their style to suit the fashion when they begin to interact with the official computer world, committed to a formal, rule-driven, hierarchical approach to programming.¹⁵ Like Lisa and Robin, their exclusion from the computer culture is perpetuated not by rules that keep them out, but by ways of thinking that make them

¹⁴ Lisa and Robin were part of a larger study of Harvard and MIT students taking introductory programming courses. The study found anxiety about an identity as a "computer person" to be an important aspect of reticence towards computers, especially among women. See Sherry Turkle, "Computational Reticence: Why Women Fear the Intimate Machine," in Cheris Kramarae, ed., *Technology and Women's Voices: Keeping in Touch* (New York: Pergamon, 1988). See also Sara Kiesler, Lee Sproull, and Jacquelynne S. Eccles, "Poolhalls, Chips, and War Games: Women in the Culture of Computing," *Psychology of Women Quarterly*, 9 (1985).

reluctant to join in. They are not computer phobic. They do not need to stay away because of fear or panic; but they are computer reticent. They want to stay away because the computer has come to symbolize an alien way of thinking. They learn to get by and to keep a certain distance. One of its manifestations is the way they neutralize the computer through language which denies the possibility of using it creatively (recall how Lisa dismisses it as "just a tool").

In this way, discrimination in the computer culture takes the form of discrimination against approaches to knowledge, most strikingly against the one preferred by Lisa and Robin, an approach we call bricolage.

3. Bricolage

Levi-Strauss used the term bricolage to contrast the analytic methodology of Western science with what he called a "science of the concrete" in primitive societies.¹⁶ The bricoleurs he describes do not move abstractly and hierarchically from axiom to theorem to corollary. Bricoleurs construct theories by arranging and rearranging, by negotiating and renegotiating with a set of well known materials.

Levi-Strauss' descriptions of the two scientific approaches, divested of his efforts to localize them culturally, suggest the variety of ways that people approach computers. For some people in our study, what is exciting about computers is working within a rule-driven system that can be mastered in a top-down, divide-and-conquer way. This is the "planner's" approach taught in the Harvard programming course. This approach decrees that the right way to solve a programming problem is to dissect it into separate parts and design a set of modular solutions that will fit the parts into an intended whole. Some programmers work this way because their teachers or employers insist that they do. For others, it is a preferred approach; to them, it seems natural to make a plan, divide the task, use modules and subprocedures.

Lisa, Robin, and others like them in our study offer examples of a very different style. They are not drawn to structured programming; their work at the computer is marked by a desire to play with the elements of the program, to move them around almost as though they were material elements—the words in a sentence, the notes in a musical composition, the elements of a collage.

The bricoleur resembles the painter who stands back between brushstrokes, looks

¹⁵ In 1987, Turkle conducted a survey of 37 women members of a local computer society. Of these, 17 reported feeling pressure to change their preferred ways of working with the computer in order to be more acceptable to the dominant computer culture. "I got my wrists slapped enough times and I changed my ways," said one of them, a college student for whom programming on her Macintosh was a private passion until she entered MIT.

¹⁶ Levi-Strauss, *The Savage Mind*. Levi-Strauss contrasted bricolage with Western science, ignoring the significant aspects of bricolage present in the latter. Several recent writers have written in a way that begins to redress this imbalance. See for example, Paul Feyerabend, *Against Method: The Outline of An Anarchistic Theory of Knowledge* (London NLB, 1975); N.R. Hanson, *Patterns of Discovery* (Cambridge: Cambridge University Press, 1958); Ludwig Wittgenstein, *Philosophical Investigations* (New York: MacMillan, 1953). In a less formal vein, see Richard Feynman, *Surely You Must Be Joking Mr. Feynman* (New York: Norton, 1985).

at the canvas, and only after this contemplation, decides what to do next. For planners, mistakes are missteps; for bricoleurs they are the essence of a navigation by mid-course corrections. For planners, a program is an instrument for premeditated control; bricoleurs have goals, but set out to realize them in the spirit of a collaborative venture with the machine. For planners, getting a program to work is like "saying one's piece"; for bricoleurs it is more like a conversation than a monologue. In cooking, this would be the style of those who do not follow recipes and instead make a series of decisions according to taste. While hierarchy and abstraction are valued by the structured programmers' planner's aesthetic, bricoleur programmers, like Levi-Strauss' bricoleurs, prefer negotiation and rearrangement of their materials.

For instance, Alex, nine years old, is a classic bricoleur. He attends the Hennigan Elementary School in Boston, the scene of an experiment in using computers across the curriculum. There, students work with Logo programming and computer controlled Lego construction materials. The work is both frequent enough (at least an hour a day) and open-ended enough for differences in styles to emerge.

When working with Lego materials and motors, most children make something move by attaching wheels to a motor that makes them turn. They see the wheels and motor through abstract concepts of what they are for: the wheels roll, the motor turns. Alex goes a different route. He looks at the objects concretely, without the filter of abstractions. He turns the Lego wheels on their sides to make flat shoes for his robot and harnesses one of the motor's most tangible features: the fact that it vibrates. When a machine vibrates it tends to travel, something normally to be avoided. When Alex runs into this phenomenon, his response is to make his robot (stabilized by its flat "wheel shoes") vibrate and thus move forward. When Alex programs in Logo he likes to keep things similarly concrete.

Learners are usually introduced to Logo programming through the "turtle," an icon on a computer screen that can be commanded to move around the screen and leave a trace as it goes. So, for example, the turtle can be told to move forward a hundred steps and turn ninety degrees with the commands FORWARD 100 RIGHT 90. Four such commands would have the turtle drawing a square. Programming occurs when a set of commands such as REPEAT 4 [FORWARD 100 RIGHT 90], are defined as a procedure: TO SQUARE. Alternatively, a subprocedure TO SIDE might be defined and repeated four times.

Alex wants to draw a skeleton. Structured programming views a computer program as a hierarchical sequence. Thus a structured program TO DRAW SKEL-ETON might be made up of four subprocedures: TO HEAD, TO BODY, TO ARMS, TO LEGS, just as TO SQUARE could be built up from repetitions of a subprocedure TO SIDE. Alex rebels against dividing his skeleton program into subprocedures; his program inserts bones one by one, marking the place for insertion with repetitions of instructions. One of the reasons often given for using subprocedures is economy in the number of instructions. Alex explains that doing it his way was "worth the extra typing" because the phrase repetition gave him a "better sense of where I am in the pattern" of the program. He had considered the structured approach, but prefers his

own style for aesthetic reasons: "It has rhythm," he says. In his opinion, using subprocedures for parts of the skeleton is too arbitrary, preemptive, and abstract. "It makes you decide how to divide up the body and perhaps you would change your mind about what goes together with what. Like, I might decide to think about the two hands together instead of each hand with the arms."¹⁷

In his own way, Alex has resisted the pressure to believe the general superior to the specific or the abstract superior to the concrete. For Alex, thinking about hands as a subset of arms is too far away from the reality of real hands, just as taking a motor that was most striking as a vibrating machine and using it to turn wheels in the standard fashion was too far away from the real motor he had before him. While the structured programmer starts with a clear plan defined in abstract terms, Alex lets the product emerge through a negotiation between himself and his material.

Anne, also nine years old, is another bricoleur programmer. Her favorite hobby is painting, and she has become expert at using sprites in programs that produce striking visual effects.¹⁸ A sprite is a second Logo icon, a turtle that can be set in motion. Once you give a sprite a speed and a heading, it moves with that state of uniform motion until something is done to change it, just like an object obeying Newton's first law.

In one of Anne's programs, a flock of birds (each bird built with a sprite) flies through the sky, disappears over the horizon, and reappears some other place and time. If all the birds were red, then it would be easy to make them disappear and reappear. The command SETCOLOR :INVISIBLE would get rid of them and SETCOLOR :RED would make them reappear. Yet Anne wants the birds to have different colors, and so making the birds reappear with their original color is more complicated.

One method for achieving this end calls for an algebraic style of thinking: you make the program store each bird's original color as the value of a variable, then you change all colors to invisible and recall the appropriate variable when the bird is to reappear. Anne knows how to use this algorithmic method, but prefers one that allows her to turn programming into the manipulation of familiar objects. As Anne programs, she uses analogies with traditional art materials. When you want to hide something on a canvas, you paint it out, you cover it over with something that looks like the background. Anne uses this technique to solve her programming problem. She lets each bird keep its color, but she makes her program hide it by placing a screen over

¹⁷ In its ideal, the structured method would have the programmer go beyond subprocedures to make one procedure that could be given different parameters to produce arms and legs, right and left sides, even differently shaped people. This aesthetic, known as "procedural abstraction," wants to see a right arm and a left leg disappear into a generalized abstract idea of "limb." But for someone like Alex, the top priority is staying in touch with the concrete. He is aware of the importance of organizing his program in order to find his way around it, but he does so by giving it what he calls "rhythm" rather than a hierarchical structure of procedures and subprocedures.

¹⁸ Anne's program has the merit of showing in compact form a set of qualities characteristic of the bricoleur, but usually more diffusely represented. For a more detailed account, see Turkle, *The Second Self*, pp. 110-15.

it. Anne designs a sprite that will screen the bird when she doesn't want it seen, a sky-colored screen that makes the bird disappear. Anne is programming a computer, but she is thinking like a painter.

Thinking like a painter does not prevent Anne from contributing a significant technical innovation to her fourth-grade computer class. She is familiar with the idea of using two sprites to form a compound object. Her classmates and teachers have always done this by putting the sprites side by side. Anne's program is like theirs in using two sprites, one for the screen, one for the bird, but she places the sprites on top of each other so that they occupy the same space. Instead of thinking of compound objects as a way of getting a picture to be bigger, she thinks of compound objects as a way of getting sprites to exhibit a greater complexity of behavior, an altogether more subtle concept.

Thus, Anne's level of technical expertise is as dazzling in its manipulation of ideas as in its visual effects. She has become familiar with the idea of data structures by inventing a new one—her screened bird. She has learned her way around a set of mathematical ideas through manipulating angles, shapes, rates, and coordinates in her program. As a bricoleur, her path into this technical knowledge is not through structural design, but through the pleasures of letting effects emerge.

As in the case of Alex, Anne does not write her program in "sections" that are assembled into a product. She makes a simple working program and shapes it gradually by successive modifications. She starts with a single black bird. She makes it fly. She gives it color. Each step is a small modification to a working program that she has in hand. If a change does not work, she undoes it with another small change. She "sculpts." At each stage of the process, she has a fully working program, not a part but a version of the final product.

Anne is perfectly capable of producing a program with well delineated subprocedures, although her way of creating them has little in common with the planner's approach.¹⁹ Devotees of structured programming would frown on Anne's style. From their point of view, Anne should design a computational object (for example, her bird) with all the required qualities built into it. She should specify, in advance, what signals will cause her bird to change color, disappear, reappear, and fly. One could then forget about "how the bird works"; it would be a black box. Anne's work dramatizes the feature of bricolage that was so salient for Lisa and Robin: the desire for transparency.

Like Lisa and Robin, she enjoys keeping open the possibility of renegotiating their exact form. This means staying in touch with that form at all times. The bricoleurs in our study tend to prefer the transparent style, planners the opaque, but the program's authorship is a critical variable in this preference. Planners want to bring their own

¹⁹ Bricolage does not exclude the use of subprocedures; it simply does not give their a priori delineation the status of a privileged method. For example, a part of a holistically conceived program can be demarcated as a subprocedure at any stage of programming. Subprocedures need not be "black boxes"; they too can be developed as the program grows as a whole. Indeed, the bricoleur may use as subprocedures programs that happen to be "lying around," possibly even programs that were originally made for very different purposes.

programs to a point where they can be black-boxed and made opaque, while bricoleurs prefer to keep them transparent; but when dealing with programs made by others, the situation is reversed. Now, the bricoleurs are happy to get to know a new object by interacting with it, learning about it through its behavior the way you would learn about a person, while the planners usually find this intolerable. The planners' more analytic approach demands knowing how the program works before interacting with it. They demand the assurance that comes from transparent understanding, from dissection and demonstration.

Despite the dominant ideology of the computer culture which privileges the structured, hierarchical, planner's style, Anne's case makes it clear that the difference between planners and bricoleurs is not in quality of product, it is in the process of creating it. In describing bricoleur programmers, we have made analogies to cooks and painters. Bricoleurs are also like writers who don't use an outline but start with one idea, associate to another, and find a connection with a third. In the end, an essay "grown" through negotiation and association is not necessarily any less elegant or easy to read than one filled in from an outline, just as the final program produced by a bricoleur can be as elegant and organized as one written with the top-down approach.

Do programmers graduate from bricolage when they develop greater expertise? Will Anne become a structured programmer in junior high? Our observations suggest that with experience, bricoleurs reap the benefits of their long explorations, so that they may appear more "decisive", and like planners when they program on familiar terrain. Also, of course, they get better at "faking it." Still, the negotiating style resurfaces when they confront something challenging or are asked to try something new. Bricolage is a way to organize work. It is not a stage in a progression to a superior form. Interviews with computer scientists and their graduate students turned up highly skilled bricoleurs, most of them aware that their style was "countercultural." Indeed, there is a culture of programming virtuosos, the hacker culture, that would recognize many elements of the bricolage style as their own.

Within feminist scholarship there is a substantial body of literature that challenges the notion that human reason best expresses itself within terms of Western male gender norms.²⁰ For example, Carol Gilligan's work on moral reasoning calls into question the idea of one privileged, mature way of thinking. Gilligan's description of two approaches to moral reasoning is analogous to our contrast between the formal, canonical approach to programming and the concrete style of the bricoleur.²¹ In the first, justice is like a mathematical principle: to solve a problem you set up the right algorithm, the right black box, you crank the handle, and the answer comes out.²² In the second, a contextualized argument is like a concrete argument, one needs to stay in touch with the inner workings of the arguments, with the relationships and possibly shifting alliances of a group of actors whose interests need to be negotiated.

²⁰ See for example the writings on scientific epistemology referred to in note ...

Despite Anne's high level of achievement, theorists of structured programming would criticize her style for the same kind of reasons that a stage theorist of moral development would classify the most impressively articulate contextual thinker at a lower intellectual level than his or her "formal" colleague. In both cases, criticism would center on the fact that neither is prepared to take the final step to abstraction. Gilligan challenges this standard hierarchy; she uses her observations of moral reasoning through concrete situations to reject Lawrence Kohlberg's stage theory with its determinate end point to development, an end point in abstract, universal principles.²³ If one branch of the development of moral reasoning moves towards the primacy of "justice," of the formal and analytic, Gilligan insists on equal respect for a different branch of development which leads toward increasingly sophisticated ways of thinking about morality in concrete terms of care through relationship and connection.

Gilligan is concerned with both morality and epistemology when she says: "the moral problem [for women] arises from conflicting responsibilities rather than from competing rights and requires for its resolution a mode of thinking that is contextual and narrative rather than formal and abstract."²⁴ Her language expresses a primary concern with the character of the morality which, as she says, requires a certain mode of thinking. This emphasis on the character of the morality (rather than the mode of thinking) is even more marked in recent writing where she redescribes Kohlberg's theory as being about only one side of moral reasoning. In this view, Kohlberg is talking about justice, thus leaving the other side of morality, namely care, to her.²⁵

This compromise which splits off the content of moral judgments from the mode of thinking about them blunts the force of Gilligan's observations as a challenge to something more general than moral reasoning; but that challenge is central to our argument. Kohlberg's theory of the development of moral judgment mirrors Piaget's theory of the development of intelligence per se. Both express the value-laden perspective on intellectual growth that has dominated Western philosophy. Piaget

²³ Gilligan, *In A Different Voice*. For a critical discussion of Gilligan's proposals and her reply see Linda K. Kerber et. al., "On In A Different Voice: An Interdisciplinary Forum," *Signs* 11, no. 2 (Winter 1986): 304-33. Its methodological criticisms of Gilligan's treatment of the relationship between "voice" and gender do not detract from how her subjects illustrate the way of thinking we call "bricolage."

²² It is an eleven-year-old, Jake, who when confronted with a moral dilemma describes it as "sort of like a math problem with humans." See Gilligan, *In A Different Voice*, p. 26

²⁴ Gilligan, *In A Different Voice*, 30ff. Kohlberg had already been challenged on other grounds. See, for example, John Gibbs, "Kohlberg's Stages of Moral judgment: A Constructive Critique," *Harvard Education Review*, 47, no. 4 (February, 1977): 43-61. Similar issues have been raised in critiques of Jean Piaget. See, for example, Steven Toulmin, *Human Understanding* (Princeton, NJ: Princeton University Press, 1972). Toulmin argues that Piaget's experimental investigations reflect an a priori commitment to a Kantian position. We single out Toulmin, because unlike most of Piaget's critics he does not quarrel with the detail of how the stages are described but with the epistemological assertion of the final end point.

²⁵ Gilligan, *In A Different Voice*, p. 19.

²⁶ Carole Gilligan and Jane Attanucci, "Two Moral Orientations," in Carol Gilligan, Janie Victoria Ward and Jill McClean Taylor, eds., *Mapping the Moral Domain* (Cambridge: Harvard University Press).

sees a progression from egocentric beginnings to a final, "formal stage" when propositional logic and the hypothetico-deductive method "liberate" intelligence from the need for concrete situations to mediate thinking.²⁶ In this vision, mature thinking is abstract thinking. We disagree: for us, formal reasoning is not a stage, but a style. Gilligan's materials on the countercultural style of moral reasoning, like the countercultural style in programming, challenges the existence of hierarchical stages: for although Piaget would place the "concrete" Anne squarely in the preformal stage, her level of achievement undermines his assumptions about the superiority of the analytic and formal.

Thus, observation of programmers at work calls into question deeply entrenched assumption about the classification and value of different ways of knowing. It provides examples of the validity and power of concrete thinking in situations that are traditionally assumed to demand the abstract. It supports a perspective that encourages looking for psychological and intellectual development within rather than beyond the concrete and suggests the need for closer investigation of the diversity of ways in which the mind can use objects to think with rather than the rules of logic.

4. Objects

Sooner or later in building objects with Lego, students at the Hennigan School where we met Alex run into the need for gears.²⁷ Looking at their work provides a good example of alternate styles applied to working with the same problem, formal styles that use rules and concrete styles that use objects.

The motors in the construction set turn at a high speed with low torque. A car built by attaching these motors directly to the wheels will go very fast, but will be so underpowered that the slightest slope or obstruction will cause it to stall. The solution to the problem with Lego cars is the same as that adopted by designers of real cars: use gears. Yet in order to use them effectively, children need to understand something about gear ratios.

If a small gear drives a larger gear, the larger gear will turn more slowly and with greater torque. It is the relative and not the absolute size of the two gears that counts. But when we interview children, we find that some of them reason as if the size of only one gear matters, as if they were following a set of rules such as "large gears are slow and strong" and "small gears are fast and weak." Without the notion of relative size, such rules fail. Other children, and in our study, predominantly the girls, are less articulate and more physical in their explanations. They squirm and twist their bodies as they try to explain how they figure things out: and they get the right answer.²⁸

²⁶ Piaget and Inhelder, *The Growth of Logical Thinking from Childhood to Adolescence*.

²⁷ These experiments with Lego and programming are undertaken in a Piagetian spirit. See Jean Piaget, *La Prise de Conscience* (Paris: Presses Universitaires de France, 1951) for experiments that deal with how mechanisms work. For a personal statement about the power of gears as an introduction to formal systems, see Seymour Papert, "The Gears of My Childhood," in *Mindstorms: Children, Computers, and Powerful Ideas* (New York: Basic Books, 1980).

Theorists who look at intellectual development as the acquisition of increasingly sophisticated rules would say that children run into problems if the rules they have built are not yet good enough.²⁹ The idea of "closeness to objects" enables us to consider a different kind of theory. Our observations suggest that the children who did so well did not have better rules, but a tendency to see things in terms of relationships rather than properties, access to a style of reasoning which allowed them to imagine themselves "inside the system." They used a relationship to the gears to help them think through a problem.

This "reasoning from within" may not be adequate for all problems about gears, but for the kind of problem encountered by the children in our project, it was not only adequate, but much less prone to the errors produced by a too-simple set of rules. Relational thinking puts you at an advantage: you do not suffer disaster if the rule is not exactly right.

We have defined bricolage as a style of organizing work that invites descriptions such as negotiational rather than planned in advance, what Warren McCulloch called "heterarchical" rather than hierarchical.³⁰ The story of the children and their gears serves to introduce another characteristic displayed by many bricoleur programmers. We call this characteristic proximality or closeness to the object. There is little distance between Anne and her computational objects. Like the children, who "reasoned from within" with the gears, Anne psychologically places herself in the same space as the sprites. She experiences her screens and birds as tangible, sensuous, and tactile. She is down there, in with the sprites, playing with them like objects in a collage. When she talks about them her gestures with hand and body show her moving with and among them. When she speaks of them she uses language such as "I move here."

The object relations school of psychoanalysis focuses on the way development progresses by a process of internalization of the things and people of the world. They come to live within us; they become the objects with which we think. When psychoanalysts talk about "objects" they usually mean people.³¹ Here we extend the idea of internalized "objects to think with" to the domain of everyday relationships with artifacts. It is not enough to ask whether individuals "like" or "don't like" to program

²⁹ Our sample does not allow us to say that girls did systematically better than boys. Research is in progress on this point. Our present discussion is about styles of explanation (rule-driven vs. body-syntonic) not distribution of abilities.

³⁰ For example most of those inspired by the Carnegie-Mellon schools of artificial intelligence. See, Ryszard S. Michalski et al., eds., *Machine Learning: An Artificial Intelligence Approach* (Los Altos, CA: Morgan Kaufmann, 1983).

³¹ For an excellent overview of the object relations perspective, see Jay R. Greenberg and Stephen A. Mitchell, *Object Relations in Psychoanalytic Theory* (Cambridge: Harvard University Press, 1983).

³² In contrast, D.W. Winnicott has some suggestive ideas about the power of the "transitional object"—the baby's blanket, the teddy bear—that in developmental terms mediates between experience of self and non-self. In the current context, it suggests the power of the inanimate in inner life. See *Playing and Reality* (New York: Basic Books, 1971).

because that puts the question on too high a level of generalization. "Liking" to program depends on forging a personally meaningful relationship with a computational object, a relationship that "fits." In forging this relationship, there are several dimensions of choice. People can choose among computational objects. For example, in the version of Logo used by Anne there was a choice between sprites and turtles. Some prefer the turtle, its static nature, the fineness in the way it draws. For others, these same qualities are reasons to reject the turtle as constraining, even unpleasant. They prefer the sprites, which move with flash and speed.

People can (and do) choose different ways of approaching the same object. Computational objects, like turtles and sprites stand on the boundary between the physical and the abstract. You can see them, move them, put one on top of another. Yet, they are mathematical constructions. Canonical programmers treat a sprite more like an abstract entity, a Newtonian particle, while bricoleur programmers treat it more like a physical object, a dab of paint or a cardboard cut-out.

Computational objects offer a great deal to those whose approach to knowledge requires a close relationship to an object experienced as tactile and concrete. Some people are comfortable with mathematical exercises that manipulate symbols on quadrille-ruled paper. For many others, computational objects offer a physical path of access to the world of formal systems. For them, the ambivalent nature of computational objects may make possible a first access to mathematics.³²

Feminist critics have related the standard notion of scientific objectivity to the social construction of gender: objectivity in the sense of distancing the self from the object of study is culturally constructed as male, just as male is culturally constructed as distanced and objective. From this point of view, Anne's proximal style is countercultural, reminiscent of Keller's description of geneticist Barbara McClintock's intimate relationship to the objects of her scientific study. For McClintock, the practice of science was essentially a conversation with her materials. The more she worked with neurospora chromosomes (so small that others had been unable to identify them), "the bigger [they] got, and when I was really working with them I wasn't outside, I was down there. I was part of the system. I actually felt as if I were right down there and these were my friends.... As you look at these things, they become part of you and you forget yourself."³³

Alex and Anne relate to computational objects much as McClintock related to chromosomes as does a successful computer science graduate student Lorraine who explains how she uses "thinking about what the program feels like inside" to break through difficult problems. "For appearances sake," she wants to "look like I'm doing what everyone else is doing, but I'm doing that with only a small part of my mind. The rest of me is imagining what the components feel like. It's like doing my pottery." This is in sharp contrast to programmers in the structured, canonical style who use their

³² Keller, *A Feeling for the Organism*, p. 117. Keller describes McClintock's approach as dependent on a capacity to "forget herself," immerse herself in observation, and "hear what the material has to say." (page 198)

favorite device of black-boxing as a way to maintain distance. The idea of the black box, designed not to be touched, mediates between the structured (planning) style of organizing work and their relationship to computational objects. Structured programmers are not among the sprites, they act on the sprites.

The contemptuous comment of one fourth-grade boy who overheard a classmate talking about "being a sprite" when he programs can be interpreted from this point of view. "That's baby talk," he said. "I am not in the computer, I'm just making things happen there." The remark reflects an insistence on boundaries and the development of a world view that will fall easily into line with the canonical, objective science whose gender-based meanings Keller has delineated.

In our research we find a close relationship between bricolage, a style of organizing work, and proximity, a style of relating to the objects of work. Our data is consistent with a model of styles as clusters of characteristics in which bricolage and proximity form the nucleus of one cluster ("concrete thinking") and planning and distance the nucleus of the other ("formal thinking"). These clusters are ideal types: our contention is not that the attributes in each cluster are exactly correlated but that each has internal coherency in the way that a stable culture is coherent.

So for example, closeness to objects tends to support a concrete style of reasoning, a preference for using objects to think with, and a bias against the abstract formulae that maintain reason at a distance from its objects. Conversely, a distanced relationship with objects supports an analytic, rule and plan oriented style. Our theoretical conjecture is that degree of closeness to objects has developmental primacy; it comes first. The child forms either a proximal or distant relationship to the world of things. The tendency to use the abstract and analytic or concrete and negotiational style of thinking follows.

Although closeness to objects favors contextual and associational styles of work, it does not exclude the possibility of using a hierarchical one. Planning is not always an expression of personal style. It can be acquired as a skill, sometimes because it is needed to get a particular job done, sometimes as a facade to hide rather than express individuality.

Indeed, our data suggest that we may be underestimating the degree of association between proximity and bricolage. Some people adopt elements of the canonical style because they feel a social pressure to do so. In order to attract less negative attention, Lisa said that she decided to be a different kind of person, i.e., more of a "planner," Robin says she "fakes it" and forces herself to black box, Lorraine affects the discourse

¹¹ In the 70 cases on which we report here, 40 grade school children and 30 college students, we found these two dimensions of approach to programming in all but 9 cases. Thus, empirically, we sometimes find each aspect of the concrete approach—bricolage as a style of organization and closeness to the object—without the presence of the other. In particular, one finds people who are planners but who enjoy a close relationship with concrete objects (and who experience computational objects this way). On the pairing of planning and what they call an interactive style with the computer, see Rosamund Sutherland and Celia Hoyles, "Gender Perspectives on Logo Programming in the Mathematics Curriculum," in Celia Hoyles, ed., *Girls and Computers* (London: Bedford Way Papers/34, Institute of Education, University of London, 1988).

of a distanced style while something very different is going on in her head. Some bricoleurs respond to the dominant ethos of the computer culture by entering into an inauthentic relationship with the computer. This can lead to a paradoxical reaction: frustrated bricoleurs appear at first sight to be extremely rigid "planners." Some turn to a "cookbook" approach—like when in third grade, we were told to divide fractions by turning "the second fraction" upside down. When denied a chance to do their "real thinking," they turn to rules that do not require them to think at all. People like Lisa and Robin "escape to conformity," a reaction that muffles the manifestation of their different voices in computing. Nevertheless, those voices are there. Recall the graduate student Lorraine, who says she tries "to look like I'm doing what everyone else is doing," in order to preserve "appearances." Her style is hidden beneath her efforts to fit in.

In our culture, the structured, plan-oriented, abstract thinkers do not only share a style but constitute an epistemological elite. We have never seen a case in which someone claims to have felt pressure to move away from the canonical style. Thus, since the phenomenon of "faking it" goes only in one direction, we conclude that true occurrence of the bricoleur/proximal combination are even more common than our raw count.

Another attribute associated with proximality and bricolage when working with computers is a tendency to anthropomorphize, to refer to the system as though it had human qualities. The anthropomorphization extends from the computational objects ("That sprite doesn't want to do what I tell it now") to the computer itself. Anne, for instance, has no doubt that computers have psychologies: "they think," she says "but can't really have emotions." She believes, however, that the computer has preferences, "He would like it if you did a pretty program." When it comes to technical things, Anne assumes the computer has an aesthetic: "I don't know if he would rather have the program be very complicated or very simple." Anne knows that the computer is just a machine, but she sees it nonetheless as a male companion, if only a limited one. Anthropomorphization, both of the computer system and its parts, does not follow from lack of technical expertise. It is a stylistic preference.³⁴

Very young children are in fact uncertain whether computers should be counted as alive or not alive, and argue the question hotly, debating the computer's aliveness on the basis of its psychology, its intentions, consciousness, and feelings. By age ten, most are sure that the computer is not actually alive. However, at this point, some children, like Anne, continue to behave with and talk about the computer as if it were sentient. They brag that it is helping them or complain that it is not. In this, they are

³⁴ Anthropomorphization is not limited to children. It is a habit of mind shared by adults, including technical experts. When we say the computer "moves the queen" in a game of chess, the program has invited us to speak of it as though it had intentions. And programs within a computer system interact with each other in a way that supports models of the computer as composed of "agents" in communication. Computer scientists talk about a concept such as recursion with anthropomorphic metaphors: one agent "calls up" another, "wakes up" another, and "passes on a job." They sometimes even refer to the agents within a computer system as citizens of a "society of mind." See Marvin Minsky, *Society of Mind* (New York: Simon and Schuster, 1987) and Papert, *Mindstorms*.

not showing confusion about biology. They do not think that the computer is alive the way an animal is, rather that it has a "kind of life," the kind of life appropriate to a computer: it thinks.³⁵

Others have a very different reaction. Once they are no longer perplexed by whether the machine might actually be alive biologically, they shy away from anthropomorphization. When they complain about the computer, they do so in objective terms: it is too slow, it does not have enough memory. Talking about the computer usually means talking about technical details.

Lise Motherwell, a researcher at the Hennigan school, did an intensive investigation of eight fifth grade students. Motherwell found she could describe children's stances towards the anthropomorphization of the computer by distinguishing two styles: relational and environmental. Relational children, like those we are calling proximal thinkers, treat the computer as much like a person as they can, while environmental children, analogous to those we describe as preferring a distanced approach, treat it like a thing.

Once they have placed the computer in the not-alive category, the environmental children tend to settle with relief into treating it as a thing. This helps them to appropriate it through a relationship that involves distance, objectivity, and control. The relational children, once having settled the question of biological aliveness, get more comfortable with the machine by making it an interactive partner. In the computer they have found something in the domain of formal systems to which they can relate with informality. Three out of the four girls in Motherwell's study were relational; three out of the four boys environmental.³⁶

In Motherwell's study, as in the study of children and gears, gender seems implicated in, but not a definitive influence on, style, consistent with observations of adult computer cultures where some men are alienated from the dominant engineering style and many women work creatively within it. Again, as in our examples of Anne, Alex, Lisa, Robin, and Lorraine, the concrete style did not imply a lower quality of work. Concrete, proximal gear builders did just as well and in some cases better than the formal thinkers; children who anthropomorphize the computer are no less technically sophisticated than those who do not. The degree of concrete, proximal, and anthropomorphic thinking does not reflect expertise but preferred approach to knowledge.

5. Gender, Closeness, and Conflict

Several intellectual perspectives suggest that women would feel more comfortable with a relational, interactive, and connected approach to objects and men with a more distanced stance, planning, commanding, and imposing principles on them.³⁷ Indeed, we have found that many women do have a preference for attachment and

³⁵ Turkle, *The Second Self*, especially chapter 1.

³⁶ Motherwell, "Gender and Style Differences in a Logo Based Environment."

relationship with computers and computational objects as a means of access to formal systems. Yet in our culture computers are associated with a construction of science that stresses aggression, domination, and competition. The cultural construction of science leads to a conflict that considerably complicates our story of how women appropriate technology. In the case of computation this conflict is particularly acute.

From its very foundations, science has defined its way of knowing in a gender-based language. Francis Bacon's image of the (male) scientist putting the (female) nature "on the rack," underscores the way objectivity has been constructed not only in terms of the distance of the knower from nature, but in terms of an aggressive relationship towards it (or rather towards her). And from its very foundations, objectivity in science has been engaged with the language of power, not only over nature, but over people and organizations. Such associations have spread beyond professional scientific communities; aggression has become part of a widespread cultural understanding of what it means to behave in a scientific way. Its methods are expected to involve "demolishing" an argument and "knocking it down" to size. Here the object of the blows is not a female nature but a male scientific opponent. If science is first a rape, it is then a duel.³⁸

The traditional discourse of computation has not been exempt from these connotations. Programs and operating systems are "crashed" and "killed." We write this paper on a computer whose operating system asks if it should "abort" an instruction it cannot "execute." In our ethnographic studies of the social worlds that grow up around computing, we have found that this is a style of discourse that few women fail to note. Thus, women are too often faced with the not necessarily conscious choice of putting themselves at odds either with the cultural associations of the technology or with the cultural constructions of being a woman.

When Lisa had a confrontation with her instructor about the proper way to program, the computer culture and its canonical epistemology were represented by a person in authority with whom she argued. In other cases the tension comes from fears of what people might think rather than a confrontation with what someone actually thinks. Lorraine who programs by imagining "what the components feel like" ends her

³⁷ Gilligan's work illuminates the relationship between bricolage and gender and Keller speaks to the gender meanings of the proximal style of relating to objects, be they physical objects such as gears or chromosomes or conceptual objects such as the elements of programming. A psychoanalytic perspective would place the roots of such approaches at an early stage of child development. If in our culture, women are the primary care takers for children, the earliest and most compelling experiences of merging are with the mother; differentiation and delineation take on gender meanings. See for example, Nancy Chodorow, *The Reproduction of Mothering: Psychoanalysis and the Sociology of Gender* (Berkeley: University of California Press, 1978) and Keller, *Reflections on Gender and Science*. The traces of such early experiences are culturally reinforced by continuing gender divisions of parenting roles and by the very different socialization of men and women.

³⁸ Keller, "Baconian Science: The Arts of Mastery and Obedience," in *Reflections on Gender and Science*, pp. 33ff; Carolyn Merchant, *The Death of Nature* (New York: Harper and Row, 1980); Donna Haraway, "The Biological Enterprise: Sex, Mind, and Profit From Human Engineering to Sociobiology," *Radical History Review* 20: 206-37.

description of her programming style by adding: "Keep this anonymous. I know it sounds stupid." In both these reactions there is a tension between an individual and an outside agency; but the conflict is internalized: the computer culture alienates by putting one in conflict with oneself.

When Lisa first found herself doing well in her programming course, she found it "scary" because she felt she needed to protect herself from the idea of "being a computer science type." In high school, Lisa saw young men around her turning to computers as a way to avoid people: "They took the computers and made a world apart." Lisa describes herself as "turning off" her natural abilities in mathematics that would have led her to the computer. "I didn't care if I was good at it. I wanted to work in worlds where languages had moods and connected you with people." Although Robin had gone through most of her life as a musician practicing piano eight hours a day, she, too, had fears about "guys who established relationships" with the computer. "To me, it sounds gross to talk about establishing a relationship with the computer. I don't like establishing relationships with machines. Relationships are for people."

In the vehemence with which many women insist on the computer's neutrality, on its being nothing more than a mere tool, there may be something more subtle going on than a clash between culture and personal style—a clash between personal style and sense of self. Many women may be fighting against having a close relationship to a computer. For some, like Lorraine, it could be because they want to belong to the dominant computer culture. But for others, the experience of closeness to the object is a source of conflict with themselves.

Lisa, like Anne, placed herself in the space of the computational objects she worked with, and she tended to anthropomorphize, responding to the computer as though it had (at least) an intellectual personality. In Lisa's case, her own style came to offend her because it had led her to what she experienced as a too-close relationship with a machine. When Lisa began programming she saw herself as communicating with the computer, but the metaphor soon distressed her. "The computer isn't a living being and when I think about communicating with it, well that's wrong. There's a certain amount of feeling involved in the idea of communication and I was looking for that from the computer." She looked for it, and she frightened herself. "It was horrible. I was becoming involved with a thing. I identified with how the computer was going through things."

In our research we find that women express such sentiments with particular urgency. We observe that a conflict fuels their convictions. In many cases, they are most comfortable with a style of thinking in which they get close to the objects of thought. The computer offers them such objects; but the closer they get to them the more anxious they feel. One remedy for their anxiety is denial. The more these people become involved with the computer, the more they insist that it is only a neutral tool. Again, their assertion is belied by the vehemence with which it is expressed.

Lisa's conflict with her instructor would be resolved in principle by a greater tolerance for her way of thinking; but addressing internal conflicts about being close to computers requires more than tolerance. It requires profound changes in the culture

that surrounds the computer. For instance, if the computer is a tool, and of course it is, is it more like a hammer or more like a harpsichord?

The musician Robin is not distressed by her close relationship with her piano which is also a machine. Lisa who finds attachment to the computer "unnatural" is not upset by her passion for the beautiful, heavy antique ink pens with which she writes. If Lisa had been in music school, it is most likely that she, like Robin, would not experience as threatening her sense of communicating with her instrument or her emotional involvement with it. Music students live in a culture that over time has slowly grown a language and models for close relationships with music machines. The harpsichord, like the visual artists' pencils, brushes and paints, is a tool, and yet we understand that artists' encounters with these can (and indeed, will most probably) be close, sensuous, and relational. Indeed, the best artists will develop highly personal styles of working with them.

6. Roadblocks and Openings for Change

The development of a new computer culture would require more than environments where there is permission to work with highly personal approaches. It would require a new social construction of the computer, with a new set of intellectual and emotional values more like those applied to harpsichords than hammers.¹⁹ Since increasingly computers are the tools people use to write, to design, to play with ideas and shapes and images, they should be addressed with a language that reflects the full range of human experiences and abilities. Changes in this direction would necessitate the reconstruction of our cultural assumptions about formal logic as the "law of thought." This point brings us full circle to where we began, with the assertion that epistemological pluralism is a necessary condition for a more inclusive computer culture.

While the computer supports epistemological pluralism, the computer culture has not. In some ways, though, the computer culture is catching up with the potential of the computer. In particular, significant openings for change within the technological culture come from a new emphasis on computational objects, which is making itself felt in domains as diverse as debates about which personal computers are the best and how to build artificial brains.

Its simplest manifestation is the use of icons to control personal computers. A traditional IBM-style computer system is controlled through typed instructions. In an iconic system, the same effects are achieved by moving screen symbols. The current technology falls short of what the computer industry expects to provide quite soon, but existing systems, such as the Macintosh's "mouse" and touch-sensitive screens already give a tactile sense that recalls Anne's experience of programming as collage.

Even superficial use of icons is enough to transform the perception of the computer by people who are using it in computationally simple ways. For example,

¹⁹ On values for a new computer culture, see Seymour Papert, "Technological Thinking versus Computer Criticism," *Educational Researcher* 16, no. 1 (January 1987): 22-30.

it is commonplace knowledge that many writers who began to use computers reluctantly, as a necessary evil, now find they have friendlier relationships mediated by the icons, the mouse, and the cozier appearance of a Macintosh. Although these particular warmer relationships do not involve programming, their influence may mean that the next generation of people like Lisa and Robin will come to programming courses with a different sense of who "owns" the computer.

A multiplicity of technical methods does not by itself lead to pluralism. It can simply lead to competition, to which the computer industry is scarcely averse, nor are those computer users who seem to enjoy heated debate about the merits of their favorite system. It is only when we understand the computer as a projective screen for different approaches to knowledge that we can listen to these conversations as a striving for pluralism. Different people are comfortable with different systems. When people fight about the IBM versus the Macintosh, what they may be trying to do is defend their intellectual styles. Yet, the debate is cast as an effort to prove the other side wrong; as if it would be impossible to prove both sides right.

A multiplicity of technical methods can also lead to elitism. The Logo language allowed Anne and Alex to program in their own ways, but in many educational settings Logo is defined as the computer language for children who have not reached the top stage in Piaget's hierarchy. In such settings, even thinkers as sophisticated as Anne, or as creative as Alex, would get their liberty at the cost of having their intellects defined as immature. Similarly, the very success of the Macintosh has often been cast in terms that reflect the elitism of the dominant computer culture. The Macintosh iconic interface has been marketed as "the computer for the rest of us," with the implication that the rest of us need things made simple and do not want to be bothered with technical things.

As it happens, the popularity of icons may be settling this argument; a conclusion which has many interpretations. The designers of computer interfaces might interpret it as final proof of the technical superiority of icons. A psychologist might read it as a challenge to the concrete/formal split; perhaps most people are concrete thinkers most of the time, and formal thinking is used for acceptability or prestige or functionality. Others might simply say that icons are "easier." Individually, these positions do not support pluralism. What is important here is whether the support for icons is part of a larger shift towards an acceptance of concrete ways of thinking.

If the shift goes far, it will be through the connection of the icons to something deeper, a philosophy of "object oriented programming."⁴⁰ In the traditional concept of a program, the unit of thought is an instruction to the computer to do something. In object oriented programming the unit of thought is creating and modifying interactive agents within a program for which the natural metaphors are biological and social rather than algebraic. The elements of the program interact as would actors on a stage. This style of programming is not only more congenial to those who favor concrete approaches, but it puts an intellectual value on a way of thinking that is resonant with their own. In principle it could undermine the canonical position in at least two ways: first, within the world of programming through legitimizing alternative methods;

second, in the larger intellectual culture, by supporting trends in cognitive theory that challenge the traditional canon.

Until recently, prevailing models of cognitive theory have bolstered the commitment of psychologists and educators to the superiority of algorithmic and formal thinking. They were given support by the cognitive theorists most influential in the computer world, the leaders of the artificial intelligence community. In the late 1970s and early 1980s, the model of AI with the greatest visibility was the rule-based "expert system" with its model of mind as a structured information processor. Critics of how computers influence the way we think cited the information processing model as demonstrating the instrumental reason and the lack of ambiguity allegedly inherent in all computational thinking about intelligence.⁴¹ Artificial intelligence is not a unitary enterprise; however, and recently, another model has become increasingly prominent: "emergent AI."⁴²

Emergent AI does not suggest that the computer be given rules to follow but tries to set up a system of independent elements within a computer from whose interactions intelligence is expected to emerge. Its sustaining images are drawn not from the logical but from the biological and social. Families of neuron-like entities or societies of anthropomorphized subminds and sub-subminds are in simultaneous interaction, from which mind-like process is expected to emerge. These models are sometimes theorized in notions of "mind as society," where negotiational processes are placed at the heart of all thinking. Those who espouse and support such models are far more inclined to find bricolage acceptable than are classical Piagetians. What concerns us here is not making value judgments about these trends in AI, just as we are not advocating a choice between the use of icons and the use of textual instructions in computer operating systems. What does concern us is that the new trends—icons, object-oriented programming, actor languages, society of mind, emergent AI—all create an intellectual climate in the computer world which undermines the idea that formal methods are the only legitimate methods.

⁴⁰ For a non-technical discussion see, Alan Kay, "Microelectronics and the Personal Computer," *Scientific American* 237 (September 1977): 230-44 and Alan Kay, "Software's Second Act," *Science* 85 (November 1985): 122ff.

⁴¹ See, for example, Hubert Dreyfus, *What Computers Can't Do: The Limits of Artificial Intelligence*, 2nd ed. (New York: Harper and Row, 1979) and Joseph Weizenbaum, *Computer Power and Human Reason* (San Francisco: W.H. Freeman, 1976).

⁴² The reaction within artificial intelligence against abstract, propositional, rule-driven methods was given literary expression in the writings of Douglas Hofstadter. See for example "Waking Up from the Boolean Dream, or Subcognition as Computation" in Douglas Hofstadter, *Metamagical Themes: Questing for the Essence of Mind and Pattern* (New York: Basic Books, 1985), pp. 631-65. Two other manifestations of this reaction are Marvin Minsky, *Society of Mind* (New York: Simon and Schuster, 1985) and David E. Rumelhart, James L. McClelland, and the PDP Research Group, *Parallel Distributed Processing: Explorations in the Microstructure of Cognition* (Cambridge MA: MIT Press, 1986. For our more extended comments on the "two AIs," see Seymour Papert, "One AI or Many" in *Daedalus*, 117, No. 1 (Winter 1988): 1-13 and Sherry Turkle, "Artificial Intelligence and Psychoanalysis," in *Daedalus*, 117, No. 1 (Winter 1988): 241-68.

Thus, recent technological developments, in interfaces, programming philosophy, and artificial intelligence, have created an opening for epistemological pluralism. We began by presenting the notion of epistemological pluralism by reference to three streams of thought—feminism, ethnography of science, and psychology—which, although different in many ways, converge in reasserting the importance of objects in thinking. We close by noting the opportunity for new alliances between them and computation.

Louis Althusser writes about psychoanalysis that the important breakthrough was not any particular statement about the mind, but the step of recognizing the unconscious as an object of study that defines a new theoretical enterprise.⁴³ Psychology long had considered the rational and the conscious as the quintessential mental activity; Sigmund Freud shifted the ground to the irrational and the unconscious. The unconscious was not given recognition as only an important factor, but rather became an object of science in its own right. Similarly, we imagine the emergence of a science of thought which would recognize the concrete as its central object.

There is every reason to think that the revaluation of the concrete will open the computer culture to accepting the computer as an expressive medium that encourages distinctive and varied styles of use. There is every reason to think that this pluralistic computer culture could be more welcoming and nurturing to women and to men. Gilligan has said that women can protect the recognition "of the continuing importance of attachment in human life."⁴⁴ The evidence from our research on programming styles leads us to conclude with an analogous speculation. Feminist scholarship could make a crucial contribution to the (until now) predominantly male computer culture by promoting the recognition of the diverse ways that people think about and appropriate formal systems and by encouraging the acceptance of our profound human connection with our tools.

⁴³ Louis Althusser, "Freud et Lacan," *La Nouvelle Critique* Nos. 161-2 (December, January, 1964-65).

⁴⁴ Carol Gilligan, *In A Different Voice*, p. 23.

Reference

- Althusser, L. (1964-65, December, January). Freud et Lacan. *La Nouvelle Critique* Nox. 161-2.
- Bleir, R. (Ed.). (1986). *Feminist approaches to science*. New York: Pergamon.
- Chodorow, N. (1989). *The reproduction of mothering: Psychoanalysis and the sociology of gender*. Berkeley: University of California Press.
- Churchland, P.M. (1989). *A neurocomputational perspective: The nature of mind and the structure of science*. Cambridge, MA: The MIT press.
- Davis, P.J. & Hersh, R. (1981). *The mathematical experience*. Boston: Houghton Mifflin.
- Dreyfuss, H. (1979). *What computers can't do: The limits of artificial intelligence* (2nd ed.). New York: Harper and Row.
- Fee, E. (1986). Critiques of modern science: The relationship of feminism to other radical epistemologies. In Bleir, R. (Ed.). *Feminist approaches to science*. New York: Pergamon.
- Feyerabend, P. (1975). *Against method: The outline of an anarchistic theory of knowledge*. London: NLB.
- Feynman, R. (1985). *Surely you must be joking Mr. Feynman*. New York: Norton.
- Field Belenky, M., McVicker Clinchy, B., Rule Goldberger, N., & Mattuck Tarule, J. (1986). *Women's ways of knowing: The development of self, voice, and mind*. New York: Basic Books.
- Fox Keller, E. (1983). *A feeling for the organism: The life and work of Barbara McClintock*. San Francisco: W.H. Freeman.
- Fox Keller, E. (1985). Baconian science: The arts of mastery and obedience. In Fox Keller, E. *Reflections on gender and science* (pp. 33ff). New Haven: Yale University Press.
- Fox Keller, E. (1985). *Reflections on gender and science*. New Haven: Yale University Press.
- Gibbs, J. (1977, February). Kohlberg's stages of moral judgment: A constructive critique. *Harvard Education Review*, 47, no.4, 43-61.
- Gilligan, C. (1982). *In a different voice: Psychological theory and women's development*. Cambridge: Harvard University Press.
- Gilligan, C. & Attanucci, J. (1988). Two moral orientations. In Gilligan, C., Ward, J.V. & McClean Taylor, J. (Eds.). *Mapping the moral domain*. Cambridge: Harvard University Press.
- Goldman, A. (1986). *Epistemology and cognition*. Cambridge, MA: Harvard University Press.
- Greenberg, J.R. & Mitchell, S.A. (1983). *Object relations in psychoanalytic theory*. Cambridge: Harvard University Press.
- Hanson, N.R. (1958). *Patterns of discovery*. Cambridge: Cambridge University Press.
- Haraway, D. (1979, Spring/Summer). The Biological enterprise: Sex, mind, and profit from human engineering to sociobiology. *Radical History Review* 20, 206-37.

- Harding, S. & Hintikka, M.B. (Eds.). (1983). *Discovering reality: Feminist perspectives on epistemology, metaphysics, methodology, and philosophy of science*. London: Reidel.
- Harel, I. (1988, June). *Software for learning: Children's construction of meaning for fractions and Logo programming*. Ph.D. dissertation, Massachusetts Institute of Technology.
- Hofstadter, D. (1985). Waking up from the Boolean dream, or Subcognition as computation. In Hofstadter, D. *Metamagical themas: Questing for the essence of mind and pattern* (pp 631-65). New York: Basic Books.
- Kay, A. (1977, September). Microelectronics and the personal computer. *Scientific American*, 237, 230-44.
- Kay, A. (1985, November). Software's second act. *Science*, 85, 122ff.
- Kerber, L.K., et al. (1986, Winter). On in a different voice: An interdisciplinary forum. *Signs*, 11, no. 2, 304-33.
- Kiesler, S., Sproull, L., & Eccles, J.S. (1985). Poolhalls, chips, and war games: Women in the culture of computing. *Psychology of Women Quarterly*, 9.
- Knorr-Cetina, K. (1981). *The manufacture of knowledge: An essay on the constructivist and contextualist nature of science*. Pergamon: Oxford.
- Knorr-Cetina K. & Mulkay, M. (Eds.). (1983). *Science observed: Perspectives on the social studies of science*. London: Sage Publications.
- Latour B. & Woolgar, S. (1979). *Laboratory life: The social construction of scientific facts*. Beverly Hills, CA: Sage.
- Lave, J. (1988). *Cognition in practice: Mind, mathematics, and culture in everyday life*. Cambridge: Cambridge University Press.
- Levi-Strauss, C. *The savage mind*. Chicago: University of Chicago Press.
- McCulloch, W. (1988). *Embodiments of mind*. Cambridge, MA: MIT Press.
- Merchant, C. (1980). *The death of nature*. New York: Harper and Row.
- Michalski R.S. et al., (Eds.). (1983). *Machine learning: An artificial intelligence approach*. Los Altos, CA: Morgan Kaufmann.
- Minsky, M. (1987). *Society of mind*. New York: Simon and Schuster.
- Motherwell, L. (1988, January). *Gender and style differences in a Logo-based environment*. Ph.D. dissertation, Massachusetts Institute of Technology.
- Papert, S. (1980). The gears of my childhood. In Papert, S. *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books.
- Papert, S. (1980). The mathematical unconscious. In Wechsler, J. (Ed.), *Aesthetics and science*. Cambridge, MA: MIT Press.
- Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books.
- Papert, S. (1987, January). Technological thinking vs. computer criticism. *Educational Researcher* 16, no. 1, 22-30.
- Papert, S. (1988, Winter). One AI or many. *Daedalus*, 117, No. 1, 1- 13.
- Papert, S., di Sessa, A., Weir, S., & Watt, D. (1979). *Final report of the brookline Logo project*. Logo Memos 53 and 54. Massachusetts Institute of Technology, Cambridge, MA.

- Piaget, J. (1950). *Introduction a epistemologie genetique*, vol. 1-3. Paris: Presses Universitaires de France.
- Piaget, J. (1951). *La prise de conscience*. Paris: Presses Universitaires de France.
- Piaget, J. & Inhelder, B. (1958). *The growth of logical thinking from childhood to adolescence*. New York: Basic Books.
- Rogoff B. & Lave, J. (Eds.). (1984). *Everyday cognition: Its development in social context*. Cambridge, MA: Harvard University Press.
- Rumelhart, D.E., McClelland, J.L., & the PDP Research Group (1986). *Parallel distributed processing: Explorations in the microstructure of cognition*. Cambridge MA: MIT Press.
- Sutherland, R. & Hoyles, C. (1988). Gender perspectives on Logo programming in the mathematics curriculum. In Hoyles, C. (Ed.), *Girls and Computers*. London: Bedford Way Papers/34, Institute of Education, University of London.
- Toulmin, S. (1972). *Human understanding*. Princeton, NJ: Princeton University Press.
- Traweek, S. (1989). *Beamtimes and lifetimes: The world of high energy physicists*. Cambridge, MA: Harvard University Press.
- Turkle, S. (1980, December). Computer as Rorschach. *Society*, 17, 15-22.
- Turkle, S. (1984). *The second self: Computers and the human spirit*. New York: Simon and Schuster.
- Turkle, S. (1988, Winter). Artificial intelligence and psychoanalysis. In *Daedalus*, 117, No. 1, 241-68.
- Turkle, S. (1988). Computational reticence: Why women fear the intimate machine. In Kramarae, C. (Ed.), *Technology and women's voices: Keeping in touch*. New York: Pergamon.
- Turkle, S., Schon, D., Nielsen, B., Orsini, M.S., & Overmeer, W. (1988, May). *Project Athena at MIT*. Unpublished manuscript.
- Weir, S. (1987). *Cultivating minds: A Logo casebook*. New York: Harper and Row.
- Weizenbaum, J. (1976). *Computer power and human reason*. San Francisco: W.H. Freeman.
- Winnicott, D.W. (1971). *Playing and reality*. New York: Basic Books.
- Wittgenstein, L. (1953). *Philosophical investigations*. New York: MacMillan.

About the Authors

Sherry Turkle, who holds a joint doctorate in sociology and psychology, is an associate professor at the Massachusetts Institute of Technology in Science, Technology and Society. She is the author of *Psychoanalytic Politics: Freud's French Revolution* and *The Second Self—Computers and the Human Spirit*.

Seymour Papert is a professor of media technology at The Media Laboratory at the Massachusetts Institute of Technology. He is the author of *Mindstorms: Children, Computers and Powerful Ideas*, *Artificial Intelligence* (the Condon Lectures) with Marvin Minsky, *Non-Counting Automata* with R. McNaughton, and *Perceptrons* with Marvin Minsky.

Becoming a Computer Scientist: A Report by the ACM Committee on the Status of Women in Computing Science

Amy Pearl
Sun Microsystems

Becky Thomas
Stanford University

Martha E. Pollack
SRI International

Elizabeth Wolf
Stanford University

Eve Riskin
University of Washington

Alice Wu
Stanford University

It is well known that women are significantly underrepresented in scientific fields in the United States, and computer science is no exception. As of 1987-1988, women constituted slightly more than half of the U.S. population and 45% of employed workers in the U.S., but they made up only 30% of employed computer scientists. Moreover, they constituted only 10% of employed doctoral-level computer scientists. During the same time period, women made up 20% of physicians and, at the doctoral level, 35% of psychologists, 22% of life scientists, and 10% of mathematicians employed in the U.S. On the other hand, there are some disciplines in which women represent an even smaller proportion at the doctoral level: in 1987-88, 8% of physical scientists, and only 2.5% of engineers were women (Report...1988).¹ The underrepresentation of women in computer science is alarming for at least two reasons. First, it raises the disturbing possibility that the field of computer science functions in ways that prevent or hinder women from becoming part of it. If this is so, those in the discipline need to evaluate their practices to ensure that fair and equal treatment is being provided to all potential and current computer scientists. Practices that exclude women are not only unethical, but they are likely to thwart the discipline's progress, as potential contributors to the field are discouraged from participation.

The second reason for concern about the underrepresentation of women in computer science relates to demographic trends in the U.S., which suggest a significant decrease in the number of white males entering college during the next decade. At the same time, the number of jobs requiring scientific or engineering training will continue to increase. Because white males have traditionally constituted the vast majority of trained scientists and engineers in this country, experts have predicted that a critical labor shortage is likely early in the next century (Changing America, 1988; Widnall, 1988). To confront this possibility, the federal government has begun to

¹ Statistics were also acquired from the U.S. Bureau of Labor Statistics in a telephone conversation.

Reprinted with permission from *Communication of the ACM*, November, 1990, published by the Association of Computing Machinery, Inc.

Strategies Encouraging Women in Computer Science

- Ensure equal access to computers for young girls and boys and develop educational software appealing to both.
- Establish programs to encourage high school girls to continue with math and science — for example, science fairs, scouting programs, and conferences in which women speak about their careers in science and engineering.
- Develop programs to pair undergraduate women with women graduate students or faculty members who serve as role models, providing encouragement and advice.
- Provide women with opportunities for successful professional experiences such as involvement in research projects, beginning as early as the undergraduate years.
- Establish programs that make women computer scientists visible to undergraduates and graduate students — for example, invite women to campuses to give talks or to serve as visiting faculty members (e.g., the NSF's Visiting Professorships for Women).
- Encourage men, as well as women, to serve as mentors for younger women in the field.
- Establish more reentry programs that enable women who have stopped their scientific training prematurely to retrain as computer scientists.
- Develop and enforce safety procedures on campus. Provide safe access at all hours to public terminal areas, well-lit routes from offices to parking lots, and services to escort those walking on campus after dark.
- Award small grants to female professors for the purchase of terminals or workstations, printers, and modems for home use for safety reasons.
- Educate all computer science faculty about self-esteem issues that women computer scientists face.
- Increase awareness of, and sensitivity to, the use of a variety of communication styles, especially less aggressive styles.
- Increase awareness of subtle discrimination and its effects.
- Develop effective grievance policies to deal with overt discrimination and sexual harassment. Implement studies of existing policies to determine what makes certain policies effective.
- Investigate ways of changing the pattern of academic careers and tenure decisions to make them more compatible with childrearing demands.
- Provide affordable, quality childcare.
- Expand parental leave policies to allow both fathers and mothers to participate actively in the rearing of small children.
- Maintain lists of qualified women computer scientists to increase the participation of women in influential positions such as program committees, editorial boards, or policy boards.

expend resources to study the problem further. A notable example is the establishment of a National Task Force on Women, Minorities, and the Handicapped in Science and Technology. Their final report, issued in December of 1989, lists a number of government and industrial programs aimed at preventing a labor shortage by increasing the number of women and minorities trained as scientists and engineers (Changing America, 1989).

In light of these facts, the Committee on the Status of Women in Computer Science, a subcommittee of the ACM's Committee on Scientific Freedom and Human Rights, was established with the goal of studying the causes of women's continued underrepresentation in the field, and developing proposed solutions to problems found. It is the committee's belief that the low number of women working as computer scientists is inextricably tied up with the particular difficulties that women face in becoming computer scientists.

Studies show that women in computer science programs in U.S. universities terminate their training earlier than men do. Between 1983 and 1986 (the latest year for which we have such figures) the percentage of bachelor's degrees in computer science awarded to women was in the range of 36-37%, while the percentage of master's degrees was in the range of 28-30%. During the same time span, the percentage of doctoral degrees awarded to women has only been in the range of 10-12%, and it has remained at that level with the exception of a slight increase in 1989 (Leveson, 1989; Report...1988). Moreover, the discrepancy between the numbers of men and women continues to increase when we look at the people who are training the future computer scientists: women currently hold only 6.5% of the faculty positions in the computer science and computer engineering departments in the 158 Ph.D.-granting institutions included on the 1988-1989 Taulbee Survey (See *Communications* September 1990). In fact, a third of these departments have no female faculty members at all (Leveson, 1989). This pattern of decreasing representation is generally consistent with that of other scientific and engineering fields (Changing America, 1988; Widnall, 1988). It is often described as "pipeline shrinkage": as women move along the academic pipeline, their percentages continue to shrink.

The focus of this report is pipeline shrinkage for women in computer science. We describe the situation for women at all stages of training in computer science, from the precollege level through graduate school. Because many of the problems discussed are related to the lack of role models for women who are in the process of becoming computer scientists, we also concern ourselves with the status of women faculty members. We not only describe the problems, but also make specific recommendations for change and encourage further study of those problems whose solutions are not yet well understood.

Of course, our focus on computer science in the university by no means exhausts the set of issues that are relevant to an investigation of women in computer science. Most notably, we do not directly address issues that are of concern exclusively or primarily to women in industry. Although some of the problems we discuss are common to all women computer scientists, there are, without doubt, other problems

that are unique to one group or the other. Nonetheless, the committee felt that an examination of the process of becoming a computer scientist provided a good starting point for a wider investigation of women in the field. Clearly, to increase the number of women in industrial computer science, one must first increase the number of women trained in the discipline. Thus, we need to consider why women stop their training earlier than men: too few women with bachelor's degrees in computer science translates into too few women in both industry and academia. Moreover, because of the documented positive effects of same-sex role models (Hornig, 1984), it is also important to consider why women drop out in higher numbers than do men even later in their academic training: too few women with doctorate degrees results in too few women faculty members. This in turn means inadequate numbers of role models for younger women in the process of becoming computer scientists.

What Is Special about Computer Science?

There are many professions in which women are underrepresented. Indeed, as we noted earlier, underrepresentation of women is a fact in most scientific disciplines, and the pipeline shrinkage pattern seen in computer science is common to most sciences. Thus, one of the first questions we need to ask is: What, if anything, is different about computer science? Are there any special characteristics of the discipline that lead to unusual problems for women? Studies addressing these questions have been undertaken by both computer scientists and social scientists, and have identified cultural factors that are significant contributors to women's special experience in computing. These factors range from influences present in elementary school educational software through the experiences of computer science graduate students.

Computers are encountered today by most children in this country more so than the artifacts of other science and engineering fields, even if they never study computer science in a formal educational setting. The earliest computer artifacts that children encounter are not gender neutral. Recreational and educational software programs reflect the gender biases and stereotypes of their designers, and studies reveal that educational software is generally designed to appeal to boys. For a host of reasons that are beyond the scope of this report, girls and boys have been shown to prefer different kinds of software programs. It is thus disturbing that, in an experimental setting, teachers instructed to design software for students tended to build programs that have the characteristics that boys prefer, and few characteristics that girls prefer—even when they are aware of these differences (Huff & Cooper, 1987).

In addition to abstract characteristics of software use, the cultural values embedded in educational software and computer games that target adolescents almost exclusively reflect what is commonly identified as adolescent male culture. The predominant themes of recreational computer games are war, battles, crimes, destruction, and traditionally male-oriented sports and hobbies (Keisler, Sproull & Eccles, 1985). Thus, it is not surprising that boys use computers in courses and summer camps both earlier and more often than do girls.

Experience in computer use, and a resulting comfort with and affinity for computing, have a strong effect on the study of computer science in the university. When college students encounter computer science, they already perceive its strong cultural component. Those who are knowledgeable about computers are differentiated by special names (wizards, hackers, wheels), and are expected to have distinguishing characteristics, language, and behaviors. This "hacker elite" system, along with the relatively new academic structure of computer science which may seem chaotic and confusing to students, results in many "computing dropouts" who are alienated by the foreign culture (Sproull, Kiesler & Zubrow, 1984). Of course, these problems may affect male as well as female students, but the situation is likely to be more pronounced for females who, because of the differences in early experiences with computers, are less likely to be a part of the elite.

The cultural factors we have described thus far appear to have an effect even on women who are making their way successfully through the computer science pipeline. A study of doctoral students in a world-class computer science department found that while male and female students exhibited comparable performance quality in their studies, the women students felt much less comfortable, confident, and successful than did the men (Burton, 1987).

It is important to acknowledge the significance of cultural influences in the acceptance and success of women in computer science culture that may act against women. Unfortunately, there are no easy solutions to this problem. There are a few specific and obvious recommendations that can be made; for instance, more educational software appealing to girls should be developed. Similarly, educators and educational institutions must make a concerted effort to ensure equal access to computers for boys and girls. However, more far-reaching solutions are less tangible. What appears to be needed is increased sensitivity on the part of male computer scientists to their female students and colleagues, an increased awareness by women so that they will not be easily discouraged, and quite simply, an increased number of women in the field.

In addition to the cultural barriers women face, they also encounter issues of physical safety. This is because, as is also the case for those in the laboratory sciences, computer scientists must often be at their workplace after dark. This is particularly true of students who often do not have computers or terminals at home. The inability to use public terminal areas after hours not only makes it difficult to complete one's assignments, but also precludes informal interactions with other students, an integral part of one's education. For more senior computer scientists after hours access to sophisticated computing systems that cannot be duplicated at home may be necessary.

All computer scientists, male and female, require safe access to the workplace, particularly at night. Yet, for obvious reasons, such access is even more essential for women. Availability of a well-lit, short route to the office from well-lit, safe parking, and a sense of safety in the department at night are crucial. It is accepted academic and professional practice to work at night, and women should be able to do so safely. As noted previously, working at home is not always possible. If working at night in the

department or on public terminals is not feasible, a woman's working hours are restricted to a subset of those available to her male colleagues. As one woman professor put it, "in many places it is a real problem to do work at night for security reasons, but it is a necessity for professional reasons" (Leveson, 1989).

One partial solution to this problem is to make campus administrators aware of the issue, so that they will address it when planning new buildings and parking areas. Also useful are services that provide escorts for those walking around campus after dark. In addition, because the issue of safety inside the office at night is equally important, it is crucial that safety procedures such as keeping the building locked at night always be followed. Consciousness-raising within computer science departments may help guarantee that safety procedures are developed and consistently followed. Finally, we should find ways to take advantage of the fact that much computer science research can be done remotely. One recommendation is that funding agencies, such as the National Science Foundation (NSF), provide small grants to female professors to purchase terminals or workstations, printers, and modems for home use, to redress partially the problem of unequal access to resources (Leveson, 1989). Male and female faculty who advise female graduate students might also find ways to loan such equipment to them. Access to computing equipment at home can also help women who are attempting to balance their careers with family responsibilities that require them to be home in the evenings. As we will describe, the conflict between these two sets of responsibilities is another source of difficulty for many women.

Other Obstacles for Women

Previously we described special characteristics of our discipline that present challenges to women who are attempting to become computer scientists or who are training future computer scientists. The majority of obstacles for women in the discipline are also shared by other women scientists and engineers, and to a lesser degree, by all other women employed outside the home. In our view, there are four primary and interrelated challenges facing women:

- Difficulties with self-esteem,
- Lack of mentoring and role models,
- Gender discrimination, and
- Difficulties balancing career and family responsibilities.

We discuss each of these problems in turn, attempting again to suggest ways to combat them. Of course, since these problems are not unique to women becoming computer scientists, the solutions we propose may also have wider applicability.

Diminished Self-Esteem

Several studies of college students have shown that women experience a much greater lack of self-esteem during their college years than do men. In the 1988 American Association for the Advancement of Science Presidential Lecture (Widnall, 1988), Sheila Widnall noted that a recent survey of graduate students in medicine,

science, and engineering at Stanford University (Zappert & Stanbury, 1984) found that

the women were indistinguishable from the men in objective measures of preparation, career aspirations, and performance in graduate school. They differed significantly in their perceptions of their preparation for graduate study, in the pressures and roadblocks that they experienced, and in the strategies that they developed for coping with these pressures...30% of the women versus 15% of the men questioned their ability to handle the work; 27% versus 12% found criticism difficult to accept; only 30% of the women versus 57% of the men felt confident speaking up in class; and 33% versus 9% feared that speaking up would reveal their inadequacies (Zappert & Stanbury, 1984, pp. 1741, 1744).

Widnall also reports on the Illinois Valedictorian Project, which followed 80 high school valedictorians (46 women, 34 men) through their college years (Arnold, 1987). At the end of their college careers, the women had a slightly higher final grade point average than the men (3.6 vs. 3.5). But the women had experienced a significantly higher loss of self-esteem. As high school seniors, about 20% of both men and women ranked themselves as "far above average," and about 45% as "above average." As college sophomores, about 20% of the men thought they were "far above average," as opposed to about 3% of the women; about 50% of the men and a little more than 40% of the women ranked themselves "above average." By their senior year, 25% of the men and *none* of the women thought they were "far above average," with about 55% of the men and 70% of the women considering themselves "above average." Overall, the self-confidence of the men increased slightly during college, while that of the women decreased significantly.

It seems clear that the diminished self-esteem of female college students contributes to the pipeline shrinkage problem. Indeed, while the studies that Widnall reports on refer to self-esteem problems of undergraduates, similar problems may be even more significant at the graduate level, where students receive primarily subjective feedback from their advisors and peers, as opposed to the more objective feedback of test scores and course grades available to undergraduates. An additional complicating factor is the differing communication styles of men and women. Studies have shown that in group settings, women are interrupted more frequently than men, and their contributions are often either attributed to men or ignored altogether (Hall & Sandler, 1982; Hall & Sandler, 1986; Widnall, 1988). Such experiences are likely to exacerbate an existing lack of self-confidence.

Diminished self-esteem may well cause a woman to not consider valid career options, because she believes that she is not sufficiently well qualified. Even women who consider themselves to be as well qualified as most of their male peers may lower their career goals when they recognize the additional problems that women may face. As Widnall points out:

A second trend noted in [the Illinois Valedictorian Project] was the lowering of career ambitions by the women students. The researchers linked lowered career ambitions in part to the unresolved dual-career problem...One of the most effective antidotes for these uncertainties about career goals was the opportunity for successful professional experiences: independent research, professional employment, opportunity for interaction with graduate students, and the support and encouragement of a faculty mentor (Widnall, 1988, p. 1743).

Those who train women to become computer scientists need to become aware of the problem of diminished self-esteem and work to combat it. Toward this end, it is important to give students unambiguous feedback concerning the quality of their work, to provide equal attention to and have equal expectations of female and male students, and to increase awareness of different, especially less aggressive, communication styles. In addition, it is essential to provide women with the opportunity for successful professional experiences. Computer science faculty need to make an effort to draw women into their research projects. While this is of course true of faculty members training graduate students, efforts to include females in research projects should ideally begin at the undergraduate level. Support must therefore be given to funding that will facilitate this, both at the national and institutional levels. An example of a model program is the National Science Foundation's Research in Undergraduate Institutions (RUI) program (NSF, 1989a), the goal of which is to provide research opportunities for undergraduates in the sciences. RUI awards are limited to projects that include significant undergraduate participation. By using programs such as the RUI to bring women to research early in their careers, faculty members may help combat diminished self-esteem in women and its impact on attrition.

Mentoring and Role Models

Another major problem facing women in the process of becoming computer scientists is a shortage of mentors. Mentors play a crucial, though usually informal, role in the training of young computer scientists. In general, a mentor shares with a less experienced colleague information about how to get research funding, avenues for publication, the informal power structure within a department and within the discipline as a whole, and so on. Mentors may invest a good deal of time in their junior colleagues and may offer them important opportunities for research collaboration.

Currently, women are much more likely than men to be mentored by female faculty members (Arnold, 1987; NSF, 1989a). However, there is no reason that men cannot serve as mentors for women, given an appropriate sensitivity to the problems that women in computer science may face. Indeed, because the number of women computer scientists shrinks as one progresses through the pipeline, it is unreasonable to expect senior women to mentor all of the junior women. Men in computer science must also support younger women.

Related to mentoring is the issue of role models. While young computer scientists can benefit from mentors of either gender, it is desirable for women to be exposed to female role models. A role model can serve as evidence that a successful career in computer science is not only a possibility, but a normal and unremarkable option for women. The existence of role models *does* matter, and it matters to women at all stages of their careers. For students, female faculty members prove, by their very existence, that Ph.D. degrees and faculty slots can be attained by women (Hall & Sandler, 1986; Hornig, 1984). A similar phenomenon is true of female faculty members who serve as role models for their more junior colleagues. Junior women who have access to senior female faculty members adjust to their positions and establish research programs more quickly than those who do not (Failor, 1990).

Of course, the only real solution to the lack of role models is to increase the number of women in computer science: Recall that only 6.5% of computer science and computer engineering faculty at the Taulbee institutions are female. However, until this situation improves, programs that make successful women more visible can help. Examples are programs that bring women scientists to campuses for a short period of time in a visiting faculty position. Activities of the former sort can be encouraged by anyone who is involved in a departmental colloquium or seminar series. Invitation for a longer period requires additional funding; one source of support is the NSF's Visiting Professorships for Women program (Sloat, 1984).

At the undergraduate level, it is useful to design programs in which undergraduates are paired with female graduate students and/or faculty. Examples of successful programs of this kind include one run by the Women's Science and Engineering Network at Stanford University (Sursock, 1987) and the Women in Science Program and the University of Michigan (Widnall, 1988). Such programs can have the additional benefit of providing graduate women with the experience of being viewed as capable and successful scientists.

Finally, we should point out that role models are important even to precollege women. Without sufficient role models, high school girls may end their mathematics and science training prematurely, thus precluding a major in science or engineering before they even begin college. High school guidance counselors and math and science teachers can play a role here by encouraging capable young women to consider science and engineering as valid career options. Several programs have been developed to encourage high school girls to acquire sufficient training to keep their options open. Perhaps the most extensive program of this kind is administered by the Math/Science Network, a non-profit organization that organizes conferences under the title of "Expanding Your Horizons in Science and Mathematics" (Failor, 1990). These conferences bring high school girls together with local female scientists. Other more local programs include science fairs, sponsored by schools, scouting troops, or similar organizations, in which women are included among the judges. To increase the influence of science fairs, they may be augmented with career awareness workshops in which participating students can meet with local scientists and engineers to learn about career paths and the educational prerequisites for technical careers.

Discrimination

The issue of gender discrimination is of course a large one that cannot be discussed in great depth here. By gender discrimination, we mean patronizing behavior and assumptions that women are less qualified and/or committed than men, regardless of whether the assumptions are conscious or unconscious. A detailed discussion of the problem of gender discrimination as it relates to women in computer science departments can be found in the 1983 report "Barriers to Equality in Academia," which was written by a group of female graduate students and research staff in the computer science department at MIT (Barriers...1983). This influential report notes that the cumulative effects of subtle discrimination may be even more harmful than relatively infrequent incidents of overt discrimination:

Often, subtle behavior is not recognized as discriminatory, for two reasons. First, the actions often are not *intended* to be discriminatory; the people who convey biased attitudes toward women may be well-intentioned. Nevertheless, the *effect* of their behavior is to undermine the professional image of women held by their colleagues and the women themselves. Second, any particular incident might appear trivial when viewed by itself. However, when women experience such incidents daily, the overall effect of the environment is much greater than the sum of the individual incidents. Because subtle discrimination is harder to recognize than overt discrimination, it sometimes does more damage. Constant exposure to negative comments diminishes a women's self-esteem and may lead her to believe that she cannot succeed (Barriers...1983, p.3).

Several reports issued by the Project on the Status and Education of Women (PSEW) of the Association of American Colleges address the subject of gender discrimination as it relates to women undergraduates, graduate students, and faculty (Hall & Sandler, 1982; Hall & Sandler, 1986). These reports concur with the MIT report's observations on the chilling effect of cumulative incidents of discrimination:

Overtly disparaging remarks about women, as well as more subtle differential behaviors, can have a critical and lasting effect. When they occur frequently—especially when they involve "gatekeepers" who teach required courses, act as advisors, or serve as chairs of departments—such behaviors can have a profound negative impact on women's academic and career development by: ...causing students to switch majors or subspecialties within majors...minimizing the development of the individual collegial relationships with faculty which are crucial for future professional development; dampening career aspirations; and undermining confidence (Hall & Sandler, 1982, p.3).

The PSEW reports, by documenting manifestations of both overt and subtle gender discrimination throughout academia, provide evidence that the problems described in the MIT report are not unique to computer science.

A recent study of several science and engineering departments also draws the connection between gender discrimination and the effective exclusion of women from first-class citizenship in their departments. The study states that "differential attention to women students was felt to promote performance stress while exclusion from informal relations was...a career handicap (Etzkowitz, Kemelgor & Neuschatz).

A particular manifestation of the differential attention paid to females in the field is what has been called the "invisibility syndrome." Not only is the percentage of women in computer science smaller than the percentage of women in the general population, but also, even within the field, women are underrepresented in many important professional activities. Ideally, the representation of women in the perceived power structure of a community should reflect their numbers in that community. One would expect reasonable, non-token representation of women on the editorial board of technical journals; as guest editors of special issues of journals; on program committees of technical conferences; as invited speakers both at conferences and at departmental colloquia; on executive boards of professional organizations such as ACM and IEEE; and on policy boards such as the Computing Research Association (formerly the Computer Research Board) and the Computer Science and Technology Board.

Unfortunately, even those women who have been successful often appear to be invisible and are not invited to participate in activities of this type to the same degree as their male counterparts. One way to address this problem is to make people aware of it, so that those whose job it is to nominate or appoint people to boards, program committees, and so forth, can make a conscious effort to include qualified women. Another solution, towards which some women in the field have begun to work, is to compile lists of qualified women in various areas of computer science who can be suggested to those who are responsible for issuing invitations and nominations.

Not only do women often find themselves subject to the type of unintentional discrimination described so far, but they may also be confronted with instances of more overt discrimination or even sexual harassment. It is therefore necessary that departments and universities develop and institute grievance procedures that guarantee confidentiality and freedom from retaliation. We recommend further study of already implemented grievance procedures to determine policies necessary to ensure their effectiveness.

The authors of the MIT study, like those of the PSEW reports, state that "responsibility for change rests with the entire community, not just with the women," and that "many problems would be alleviated by increasing the number of women" (Barriers... 1983). We agree completely, and recommend that the kinds of actions we have proposed elsewhere in the report be adopted to help increase women's representation in the field.

Balancing Responsibilities

A final issue that is of central concern involves the difficulties in balancing the responsibilities of a career in computer science with the responsibilities of raising a

family. Concern with this problem may lead young women to abandon the possibility of a career in computer science (or any other science) at a very early stage in their training, as indicated in the quotation from the Widnall report noted earlier ("researchers linked lowered career ambitions in part to the unresolved dual-career problem"). Actual difficulties encountered in achieving this balance may result in women leaving computer science later in their careers. Of course, in their concern with this problem, women considering or pursuing careers in computer science are not very different from women in a wide range of other careers—or, for that matter, from many men in those careers. Last April, a *New York Times* article noted, "fathers, too, are seeking a balance between their families and careers." However, while achieving such a balance may be difficult for people pursuing many different careers, there are certain aspects of a tenure-track position in a scientific field that render the balancing act particularly difficult (Marriage...1989).

The typical "tenure-track" career path appears to be generally incompatible with outside interests and responsibilities including, but not limited to, childbearing and rearing. Junior faculty in tenure-track positions (like junior lawyers working towards partnerships, junior investment bankers trying to become vice presidents, etc.) are expected to devote enormous amounts of time and energy to their careers: so much time and energy that serious outside interests are precluded or at least greatly constrained. The model for an academic career was developed during a time in which faculty positions were primarily occupied by men who had wives to tend to their home responsibilities. We call this the *helpmate-in-the-background* model. It is one that is still present today: An illustration can be found in the acknowledgments statement of many academic books. An example, from a recent book authored by a male computer scientist, includes a statement of gratitude to his wife "for sheltering [him] from the travails of the real world."

The problem is that the helpmate-in-the-background model is inappropriate for today's society, in which both men and women should have the right, and often have the obligation, to have careers. The model is most obviously inappropriate for women. Women *were* the helpmates-in-the-background: They do not typically have helpmates of their own.

Further complicating the situation is the fact of women's "biological clocks." Most students do not complete the Ph.D. until the middle 30's. Hence, the childbearing years directly coincide with the period of time during which a woman is completing her Ph.D. and working toward tenure. Both rearing small children and achieving tenure are tremendously time-consuming efforts; doing both at the same time seems to many women to be exceptionally difficult, if not impossible (Etzkowitz, Kemelgor & Neuschatz).

There are a number of things that can be done to help women achieve a balance between family responsibilities and career demands. For example, universities can and should provide affordable, quality childcare. Sufficient maternity leave policies are also necessary. Many universities have no formal leave policy at all, while others grant only minimal leaves (e.g., one month or less). A few will allow women a

semester off from teaching responsibilities at reduced pay. At those universities that do not offer this option, female faculty are often put in the position of having to try to "time" their babies for semesters that they had planned to take off anyway, such as summer semesters, sabbatical periods, or semesters during which they used grant money to "buy out" of teaching. However, the first of these options is often not viable because most computer science faculty do not have the summer off; instead, they use this period to work on research grants, generally a requirement for tenure. The latter two options generally require that the women already have tenure or at least be fairly close to it. Moreover, attempts to schedule a baby's arrival are far from reliable and often fail. Thus, better maternity leave policies are obviously needed.

But solutions like these do not go far enough. Fundamental changes in the patterns of academic careers are required. These changes must rest on a realization that it is the responsibilities of *parenting* a small child, and not the responsibilities of *mothering* a small child, that are incompatible with current work requirements. The model of a helpmate-in-the-background should be as untenable for men in today's society as it is for women.

It is true that there are issues that will always be specific to women—pregnancy, childbirth, and lactation—and career paths must be designed with these in mind. But there are other realities of women's lives that should be seen merely as traditionally women's. Many of these can and should be shared by men. For example, universities must develop not just maternal policies, but parental policies that will allow male as well as female faculty members to be involved in the rearing of small children. Many universities today provide no parental leave at all. Yet, fathers not only need time off immediately after the birth of a child, but also, like mothers, need reduced workloads for an extended period of time, to enable them to participate in the rearing of their small children. Thus, another important policy that must be developed, for both men and women, involves changing the way in which the tenure clock operates.

As with maternity leaves, different universities have different policies regarding slowing the tenure clock to allow a faculty member to care for a small child. Differences involve: 1) whether any slowing of the tenure clock is allowed at all; 2) whether it is permitted only for the "primary caretaker" or whether it is permitted for both parents; 3) whether it is permitted for adoptions; 4) the period of time for which the clock is stopped (typically, one semester); 5) the number of children for which this is allowed (typically one, sometimes two). In our view, some kind of reduced work load is essential to permit faculty members who wish to do so to better balance their family responsibilities with their careers. Moreover, this option should be available to fathers as well as mothers. There have been some doubts expressed about this solution: The claim is that fathers will "take advantage" of the situation by stopping the tenure clock even though they are not participating heavily in the rearing of their child. The worry is that if this happens, the default tenure period will simply become seven years instead of six, and women who do take primary responsibility for the rearing of their children will once again be at a disadvantage.

In our view, this possibility must be faced, but it appears that one solution is to make a strong effort not to change the standards for tenure. That is, departments must continue to impose the same tenure requirements as they do now, but must assume that some faculty members will take seven or eight years to meet those requirements rather than six. We need to expect that faculty members may take the extra year or two even if they do not have additional child-rearing demands. As long as the standards are not raised, which would penalize those with additional responsibilities, this is not a dire consequence.

Because the issues surrounding leave policies, deferred tenure, and related issues are so complex, we recommend a systematic study of policies in academic departments to better evaluate the options. It is even possible that the conclusion of such a study will be that the entire tenure process is incompatible with the demands of a dual-career society. After all, the demands of rearing a small child do not stop after six weeks or one semester or even one year of a leave. When the helpmate-in-the-background model is thrown out, it needs to be replaced with a much more flexible one in which people are free to move on and off of a "fast track" at different stages in their career, without those moves permanently jeopardizing that career. This is exactly what tenure precludes: If a faculty member is not fully committed to his or her academic career during the very same period of time in which he or she is most likely to face the demands of raising small children, tenure is unlikely to be granted, and the academic career will be permanently stalled.

Although we have emphasized that the traditional helpmate-in-the-background model works against women with children, we believe it also works against women without children and men with employed wives. Few of these people have such helpmates.

In our view, it is important to work to change the helpmate-in-the background model. It must be possible for both women and men to work hard and well at a career, without neglecting their personal lives. We believe this will eventually be advantageous for both men and women. There is great satisfaction to be found in one's work, but there is also great satisfaction to be found in one's personal life. No one should have to choose one at the expense of the other.

Reopening the Pipeline

As a result of the kinds of problems we have discussed, many women have dropped out of the computer science pipeline prematurely. Although we have been focusing on ways to reverse this trend, an additional approach to correcting the problem of underrepresentation is to help women reenter the pipeline after dropping out of it early. One example of a particularly successful reentry program is the University of California at Berkeley program, which has been in existence since 1983. It is aimed at making graduate study in computer science possible for women and minority students who have received a bachelor's degree in another field. Students in the Berkeley reentry program take regular computer science courses along with undergraduates, and in addition receive a host of support services. The program has

been producing graduates for seven years now, and students who have completed the program have been quite successful in gaining admission to competitive graduate programs in computer science (Grigolia, 1990).

A second set of women for whom reopening the pipeline may be useful are those with science degrees who are not employed in science. A 1976 NSF program, called the Science Career Facilitation (SCF) Projects, was aimed at such women. This extensive program, which was later discontinued, funded 21 projects in fields where women were poorly represented even though jobs were readily available. Three of these 21 projects dealt with women reentering computer science.

An evaluation of the SCF projects led to several important findings. The primary reasons most women cited for having dropped out of science involved family responsibilities. Research supported by the SCF projects surveyed more than 2000 organizations providing potential employment to scientists, and revealed that none of them attended to the needs of reentering women. Yet programs that do address this would appear to be very useful: after all, more than 585,000 women scientists expressed an interest in retraining and reentry. Finally, the SCF projects that provided this retraining were quite successful: in total, 65% of the participants were reemployed in science while another 10% became full-time graduate students (Lantz, 1982).

Conclusions

We have presented some of the problems facing women who are in the process of becoming computer scientists, as well as the women who are training them, and we have made recommendations for change (see sidebar). There appear to be clear and relatively easily implemented solutions for some problems, while for others, such as the apparent conflict between child-rearing and gaining tenure, the issues are more complex, and further study is required to develop effective solutions. Indeed, complete resolution of some of these problems will depend upon significant societal changes. Ultimately, everything hinges on increasing the number of women in the field. We must make sure that increased representation of women is not stalled because of policies or practices of computer science educators or employers.

Obviously, this article is not comprehensive. We have not, for example, addressed problems unique to women in industrial computer science, nor have we considered how the problems we have described are exacerbated for women of color or disabled women. We believe it is important that these issues be examined, but we leave them for other articles.

Acknowledgments

The authors wish to thank Barbara Simons for suggesting and initiating this work and Sheila Humphreys for her support and input. In addition, we would like to thank Nita Goyal, Paula Hawthorn, Kathy McCoy, Shari Pflieger, Anthony Ralston, Eric Roberts, Candy Sidner, the Systers list for helpful comments and discussions, and the Committee on Scientific Freedom and Human Rights for its support. We also thank those who participated in a pilot survey that we conducted to try to elicit additional information about women in the process of becoming computer scientists.

References

- American Association for the Advancement of Science. Marriage, family, and scientific careers: Institutional policies versus research findings. (1989). In *Proceedings of a Symposium at the Annual Meeting of the AAAS*.
- Arnold, K. (July 1987). Retaining high-achieving women in science and engineering. In *AAAS Symposium on Women and Girls and Technology*. Univ. of Michigan, Ann Arbor, Michigan.
- Barriers to equality in academia: Women in computer science at MIT. Laboratory for Computer Science and the Artificial Intelligence Laboratory at M.I.T., 1983.
- Burton, M. D. (1987, June). Gender differences in professional socialization: A study of women and men becoming computer scientists. Tech. Rep., Pittsburgh, PA: Carnegie-Mellon University, Committee on Social Science Research in Computing, Social and Decision Science Department.
- Etzkowitz, H., Kemelgor, C., & Neuschatz, M. The final disadvantage: Barriers to women in academic science and engineering. Tech. Rep., Rensselaer Polytechnic Inst. Center for Science and Technology.
- Failor, B. (1990, Winter). The history of EYH. *Math/Science Network Broadcast*, 5.
- Gilbert, L., Gallesich, J.M., & Evans, S. L. (1983). Sex of faculty role model and students' self-perceptions of competency. *Sex Roles*, 9 (5), 597-607.
- Grigolia, M. (1990, April 19). Computer science reentry program. *Computer Research News*, 2(2).
- Hall, R. M. & Sandler, B. R. (1982). The classroom climate: A chilly one for women? Project on the Status and Education of Women. Association of American Colleges, Washington, D.C.
- Hall R. M. & Sandler, B. R. (1986). The classroom climate revisited: Chilly for women faculty, administrators, and graduate students. Project on the Status and Education of Women, Association of American Colleges, Washington, D.C.
- Hornig, L. S. (1984). Women in science and engineering: Why so few? *Technology Review*, 87(8), 31-41.
- Huff, C. & Cooper, J. (1987). Sex bias in educational software: The effect of designers' stereotypes on the software they design. *Journal of Applied Social Psychology*, 17(6), 519-532.
- Kiesler, S., Sproull, L., & Eccles, J. S. (1985). Pool halls chips, and war games: Women in the culture of computing. *Psychology of Women Quarterly*, 9, 451-462.
- Lantz, A. (1987). An evaluation of programs for reentry of women scientists. In S. Humphreys (Eds.), *Women and minorities in science: Strategies for increasing participation*. Westview Press.
- Leveson, N. (1989). Women in computer science: A report for the NSECISE Cross Directorate Activities Advisory Committee.
- Long, J. S. The origins of sex differences in science. *Social Forces*. To be published.
- National Science Foundation. (1989a). Research in undergraduate institutions (RUI). Program Announcement, Directorate for Scientific, Technological, and International Affairs. Washington, D.C.: author.

- National Science Foundation. (1989b, October). Visiting professorships for women. Grants for Research and Education in Science and Engineering Program Announcement. Washington, D.C.: author.
- National Science Foundation. (1988). Report on women and minorities in science and engineering. Washington, D.C.: author.
- Sloat, B. (1984, April). Women in science: A university program of intervention, outreach, and research. In *Second International Interdisciplinary Congress on Women*. Gorningen, the Netherlands.
- Sproull, L. S., Kiesler, S., & Zubrow, D. (1984). Encountering an alien culture. *Journal of Social Issues*, 40(3), 31-48.
- Sursock, A. (1987). The women's science and engineering network. *European Journal of Physics*, 8 (2), 151-152.
- The Task Force on Women, Minorities, and the Handicapped in Science and Technology. (1988). Changing America: The new face of science and engineering. (Interim Report). Washington, D.C.: author.
- The Task Force on Women, Minorities, and the Handicapped in Science and Technology. (1989). Changing America: The new face of science and engineering. (Final Report). Washington, D.C.: author.
- Widnall, S. E. (1988). AAAS Presidential Lecture: Voices from the pipeline. *Science*, 241, 1740-1745.
- Zappert, L. T. & Stanbury, K. (1984). In the pipeline: A comparative analysis of men and women in graduate programs in science, engineering, and medicine at Stanford University. Tech. Rep. Working Paper 20, Institute for Research on Women and Gender, Stanford University Stanford, CA.

About the Authors

Amy Pearl is a member of the Technical Staff at Sun Microsystems. She earned her M.S. at Stanford University in 1986, with a concentration in distributed systems. Her interests are development of software tools and mechanisms in the areas of hypertext and large software engineering projects.

Dr. Martha E. Pollack is a computer scientist in the Artificial Intelligence Center at SRI International and a Senior Researcher at the Center for the Study of Language and Information at Stanford University. She earned her Ph.D. at the University of Pennsylvania in 1986. Her research areas are AI plan generation and recognition, experimental evaluation of AI systems, and natural-language semantics and pragmatics.

Dr. Eve A. Riskin is an Assistant Professor in the Department of Electrical Engineering at the University of Washington. She earned her Ph.D. in electrical engineering from Stanford University in 1990. Her research interests include image compression and processing, medical imaging, and pattern recognition.

Becky Thomas is working on a Ph.D. in computer science at Stanford University. She earned her B.S. in electrical engineering at M.I.T. in 1987. Her research area is formalisms for representing and reasoning about time, knowledge, and action.

Elizabeth Wolf is working on a Ph.D. in computer science at Stanford University. She earned her B.A. in computer science and in applied mathematics at the University of California at Berkeley in 1986 and her M.S. in computer science at Stanford University in 1989. Her research interests are mathematical theory of computation and formal verification.

Alice Wu is currently pursuing her M.S. in the Computer Science Department at Stanford University. She earned her B.S. in computer science from Stanford University in 1990. Her concentration is in software systems design with emphasis on user interface and human-computer interaction.